CoCo-80 Basic DSA User's Manual

Version 1.3

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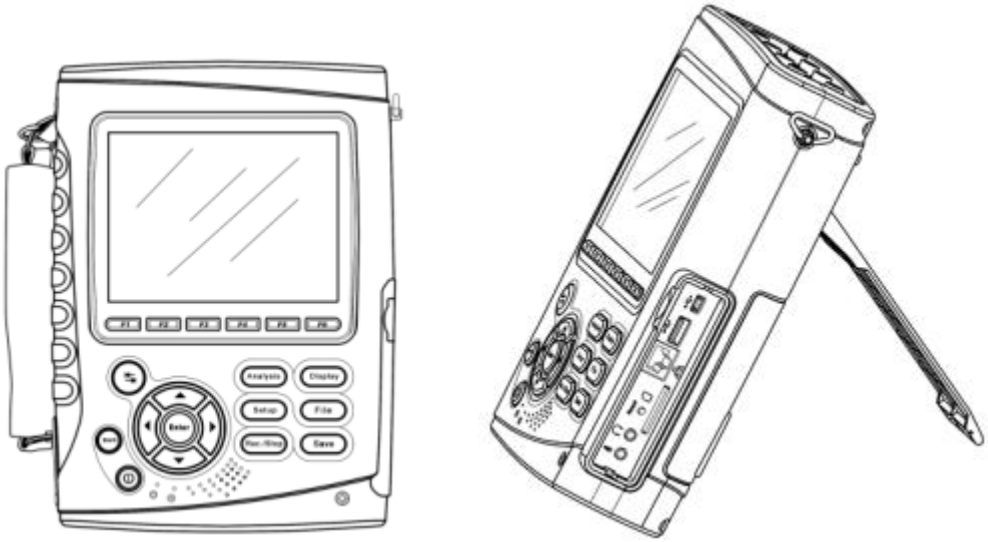
1. INTRODUCTION

CoCo-80 is a handheld data recorder, dynamic signal analyzer and vibration data collector that is ideal for a wide range of industries including machine conditioning monitoring, automotive, aviation, aerospace, electronics and military that demand easy, quick and accurate data recording and real-time processing in the field. CoCo-80 is a low-cost, light-weight, battery powered handheld system with unparalleled performance and accuracy. The user interface of CoCo-80 is specifically designed for easy and simple operation while it maintains the capability of providing a wide variety of analysis functions.

The CoCo-80 hardware platform supports two different software working modes: dynamic signal analyzer (**DSA**) and vibration data collector (**VDC**). Each working mode has its own user interface and operation navigation structure. DSA working mode is designed for mechanical structure analysis, testing and optimization or for electrical, geophysics and a wide range of applications. VDC is dedicated to route-based machine vibration data collection and trending. The user will select one of the working modes to execute. This manual describes the DSA working mode of CoCo-80.



- Figure 1. CoCo-80 Hardware.

CoCo-80 is the first battery-powered handheld data acquisition system that matches the performance and functionality of higher-end systems. CoCo-80 is equipped with 4 or 8 input channels and can accurately measure and record both dynamic and static signals. The mass flash memory can record 8 channels of streaming signals simultaneously up to 102.4 kHz. An embedded signal source channel provides various signal output waveforms that are synchronized with the input sampling rate.

CoCo-80 hardware uses dual CPU architecture. An XScale CPU handles the user interface, project configuration, power management, network communication as well as all the peripherals. A

high-speed floating point DSP manages the data input/output and real-time processing. CoCo-80 is also configured with large RAM and NAND flash memory for mass data storage. Special thermo and low power design eliminates the need for a cooling fan and increases the battery operating time. Proprietary hardware technology delivers more than 130 dB dynamic range. The extremely high dynamic range eliminates the need for multiple front end gain settings.

The CoCo-80 can also be operated from a DC power source (which will also simultaneously charge the battery). This can be achieved with either the CoCo-80 AC-DC Adapter (P/N 40-115) or an Automotive Cigarette Lighter Adapter.

Revolutionary 24-bit A/D converters, digital technology and unique hardware designed for CoCo-80 offers more than 130 dB dynamic range, 10~100 times higher than competitive products. The high dynamic range and fidelity of the CoCo-80 enables measurement of a wide range of signals, regardless of the input signal magnitude.

CoCo-80 excels in both dynamic and static measurements. When used for dynamic measurements, the input channels offer extremely high-quality dynamic range, signal to noise ratio, cross channel gain match, phase match, and spectrum flatness over an analysis frequency range up to 45 kHz. When it is used to measure the static or quasi-static signals, it offers very high accuracy at DC or near DC frequency.

The CoCo-80 utilizes a new signal processing method, Configurable Signal Analysis (CSA). CSA provides unique flexibility for real time analysis including filtering and spectral analysis.

For DSA applications the CoCo-80 software stores and organizes the data in the popular ASAM-ODS standard. Data may be exchanged with other data formats such as UFF, BUFF, NI-TDM. ASCII, MATLAB or Excel. The ASAM-ODS data standard provides ultimate flexibility and version compatibility. ASAM-ODS data standard is widely supported by the automotive industry and is expanding to aerospace and other areas. For VDC applications the CoCo data is stored and managed by the database.

The handheld system is equipped with two USB ports, 100 BaseT Ethernet, SD-card interface, audio input/output, 5.7 inch color LCD display and a keypad. You can connect the CoCo-80 to a PC, download files and upgrade the software through several means of network connection. The user interface of CoCo-80 is specifically designed for easy and simple operation while it maintains the capability of providing a wide variety of analysis functions.

The CoCo-80 has a weight less than 1.7 kg. Advanced thermal design eliminates the need for a cooling fan reducing operating noise. The fully charged battery life is up to many hours. An AC adapter can be used any time to charge the device and supports unlimited hours of operation.

Compared to handheld data acquisition systems and signal analyzers from the other providers, CoCo-80 delivers a higher measurement dynamic range and accuracy, recording throughput rate and real-time analysis performance. It also provides more powerful communication peripherals.

Compared to PC-tethered data acquisition systems and signal analyzers, CoCo-80 does not have the drawbacks such as unreliable data transfer using connection cables. CoCo-80 does not need any additional PC or laptop to operate during field data acquisition. Hence CoCo-80 is much more reliable and easy to operate.

On-Line Support

To access product information about your CoCo-80, please go to the product page of CI website at: http://www.go-ci.com/support.asp, log in with the serial number of the CoCo-80 and the password included in your shipping documents. After you log-in, you will be able to review and download the latest information which is restricted to CoCo80 users, including:

- Product Information
- New CSA projects
- User's Manual
- Shipping and Repair History
- User Forum
- Technical Support
- Software Updates
- Technical Issues

A typical page of CI Technical Support website is shown below:

■ Figure 2. Crystal Instruments CoCo-80 Support Website.

The latest CoCo-80 application software, device drivers or CSA projects can be downloaded while the CoCo-80 subscription is maintained.

Limited Warranty & Limitation of Liability

Each CI product is warranted to be free from defects in material and workmanship under normal use and service. The warranty period is one year for the CoCo-80 hardware and its accessories. The warranty period begins on the date of shipment. Parts, product repairs and services are warranted for 90 days. This warranty extends only to the original buyer or end-user customer of a CI authorized reseller, and does not apply to fuses, disposable batteries or to any product which, in CI's opinion, has been misused, altered, neglected or damaged by accident or abnormal conditions of operation or handling. CI warrants that software will operate substantially in accordance with its functional specifications for one year and that it has been properly recorded on non defective media. CI does not warrant that software will be error free or operate without interruption.

CI authorized resellers shall extend this warranty on new and unused products to end user customers only but have no authority to extend a greater or different warranty on behalf of CI. Warranty support is available if the product is purchased through a CI authorized sales outlet or the Buyer has paid the applicable international price. CI reserves the right to invoice the Buyer for importation costs of repair/replacement parts when product purchased in one country is submitted for repair in another country.

CI's warranty obligation is limited, at CI's option, to refund of the purchase price, free of charge repair, or replacement of a defective product which is returned to a CI authorized service center within the warranty period.

To obtain warranty service, contact your nearest CI authorized service center or send the product, with a description of the difficulty, postage and insurance prepaid (FOB Destination), to the nearest CI authorized service center. CI assumes no risk for damage in transit. Following warranty repair, the product will be returned to Buyer, transportation prepaid (FOB Destination). If CI determines that the failure was caused by misuse, alteration, accident or abnormal condition of operation or handling, CI will provide an estimate of repair costs and obtain authorization before commencing the work. Following repair, the product will be returned to the Buyer transportation prepaid and the Buyer will be billed for the repair and return transportation charges.

THIS WARRANTY IS THE BUYER'S SOLE AND EXCLUSIVE REMEDY AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. CI SHALL NOT BE LIABLE FOR ANY SPECIAL, INDIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES OR LOSSES, INCLUDING LOSS OF DATA, WHETHER ARISING FROM BREACH OF WARRANTY OR BASED ON CONTRACT, TORT, RELIANCE OR ANY OTHERTHEORY.

Since some countries or states do not allow limitation of the term of an implied warranty, or exclusion or limitation of incidental or consequential damages, the limitations and exclusions of this warranty may not apply to every buyer. If any provision of this Warranty is held invalid or unenforceable by a court of competent jurisdiction, such holding will not affect the validity or enforceability of any other provision.

Crystal Instruments Corporation, www.go-ci.com

Safety Information: Read First

The CI CoCo-80 Handheld Data Acquisition System complies with:

EN 61326:1997+A1:1998+A2:2001
EN61000-3-2: 2000 & EN61000-3-3: 1995+A1:2001

Use the CoCo-80 and its accessories only as specified in the User's Manual. Otherwise, the protection provided by the Instrument and its accessories might be impaired.

Condensation may form on the circuit boards when the device is moved from a cold environment to a warm one. In these situations, always wait until the device warms up to room temperature and is completely dry before turning it on. The acclimatization period should take about 2 hours.

For the most accurate measurements a warm-up phase of 20 min is recommended.

The devices have been designed for use in clean and dry environments. It is not to be operated in 1) exceedingly dusty and/ or wet environments, 2) in environments where danger of explosion exists nor 3) in environments containing aggressive chemical agents.

Lay cables in a manner to avoid hazards (tripping) and damage.

A Warning identifies conditions and actions that pose hazard(s) to the user. A Caution identifies conditions and actions that may damage the Instrument.

To avoid electrical shock or fire:

1. Realize that the CoCo-80 is a low voltage measurement instrument.
2. Do not apply input voltages above the rating of the Instrument. You should never apply a voltage that potentially exceeds +/-40V to the Instrument.
3. Review the entire manual before use of the Instrument and its accessories.
4. Do not operate the Instrument around explosive gas or vapor.
5. Before use, inspect the instrument, BNC connectors and accessories for mechanical damage and replace when damaged. Look for cracks or missing plastic. Pay special attention to the insulation surrounding the connectors.
6. Remove the cables and accessories that are not in use.
7. Use the ground input only to ground the Instrument and do not apply any voltage.
8. Do not insert metal objects into connectors.
9. Use only the wall-mount power supply provided by the Crystal Instruments.

AC Adapter Voltage Range

For external power source CoCo-80 uses a wall-mount AC Adapter. The AC Power range is: 100Vac ~ 240Vac.

Maximum Measurement Input Voltage

Maximum Working Input Voltage: 10 V peak. Voltage ratings are given as "working voltage". They should be read as Vpeak for dynamic applications and as V dc for DC applications.
Max. Input Range without damaging the hardware: 40Vpeak.

If Safety Features are Impaired

If the instrument is used in a manner not specified by the manufacturer, the protection provided by the instrument may be impaired. Before use, inspect the test leads for mechanical damage and replace damaged test leads! If the instrument or its accessories appear to be impaired or not functioning properly, do not use it and send it in for repair.

2. QUICK START

This Quick Start section is intended to give a brief introduction to the most basic use of the CoCo-80 system. By following the instructions you will learn how to do the following:

1. Record Time Streams with CoCo-80
2. Install the EDM software to your host PC
3. Download and view the data on host the PC

After completing the Quick Start tutorial you should read the following sections for a more comprehensive description of the system.

Recording Time Streams with CoCo-80

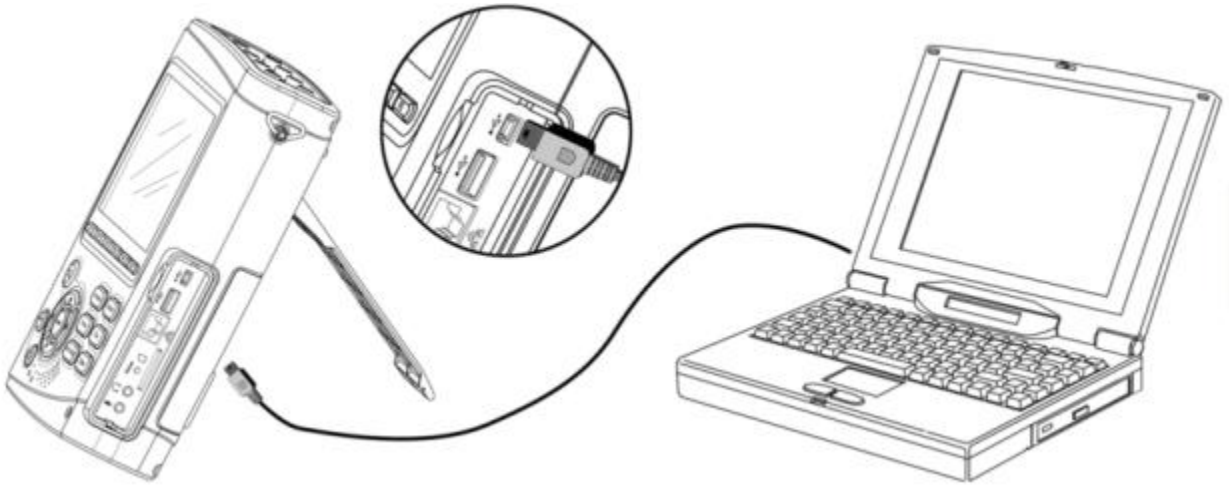
1. Remove the CoCo-80 unit from the shipping packaging.
2. Connect the wall mount power adaptor to the 110V/220V power outlet.
3. Connect the wall-mount power adaptor to the CoCo-80 (if battery is not charged).
4. Push the power button on CoCo-80, wait for about 30 seconds until the Welcome screen is displayed.
5. Use the Up or Down arrow buttons to select one of the CSA project files to run.
6. In the signal display screen, press ***F2 (Param.)*** and select ***Time Stream Recording Setup*** to define data streams for recording. To enable the recording for any signal, first use the up/down arrow navigation buttons to move to the signal, then press the Enter button to select or de-select.
7. Push the ***Rec./Stop*** button to record the signals. After a few seconds push the ***Rec./Stop*** button again to stop the recording.
8. Push the ***File*** button, then the Files soft button to review the recorded signals.

Install Engineering Data management (EDM) software to PC

1. Insert the CoCo-80 Application Software CD into your host computer.
2. Click Install EDM entry to install the EDM software and follow the instructions.
3. Set a local working folder to your computer.

Download Data to the PC

1. Connect the CoCo-80 to your PC using the USB cable provided. Note there are two USB ports on the CoCo-80 device. Connect the USB cable to the USB-client connector shown below.



- Figure 3. Client USB connector for PC communication.

2. Browse for the device driver on the CD and the Windows operating system will automatically install the CoCo-80 USB driver on the PC.

3. Run the EDM software from the host PC.

4. Click on the Search Button on EDM to search the CoCo-80 devices that are connected to the PC.

5. After the EDM finds the CoCo-80, click Connect.

6. Drag the data file from the CoCo-80 (xxx.atfx), to one of your local folders.

7. Using the mouse, right click on the signal file xxx.atfx on your local folder, and click ***View*** from the pop-up menu.

8. Now the EDM software changes to the Analysis page. Use the mouse to drag the signal ch1 into the center empty area. You will see the waveform that you just recorded with CoCo-80.

After completing this short Quick Start tutorial you should read the following sections and review the complete Users' Manual for a detailed description of the features and operating instructions.

Important Notice about the Concept of CSA

CSA stands for **C**onfigurable **S**ignal **A**nalysis. The first time you use the CoCo-80, you may wonder why some of the signals, or functions, are missing when you run the CSA files. For example, when **DefaultTime(4)** runs, you will find it does not support any acquisition mode, any transient capture

or any spectral analysis. You may wonder if this is a software bug. The answer is no. Whether these features are available or not are determined when the CSA project is edited on the host PC.

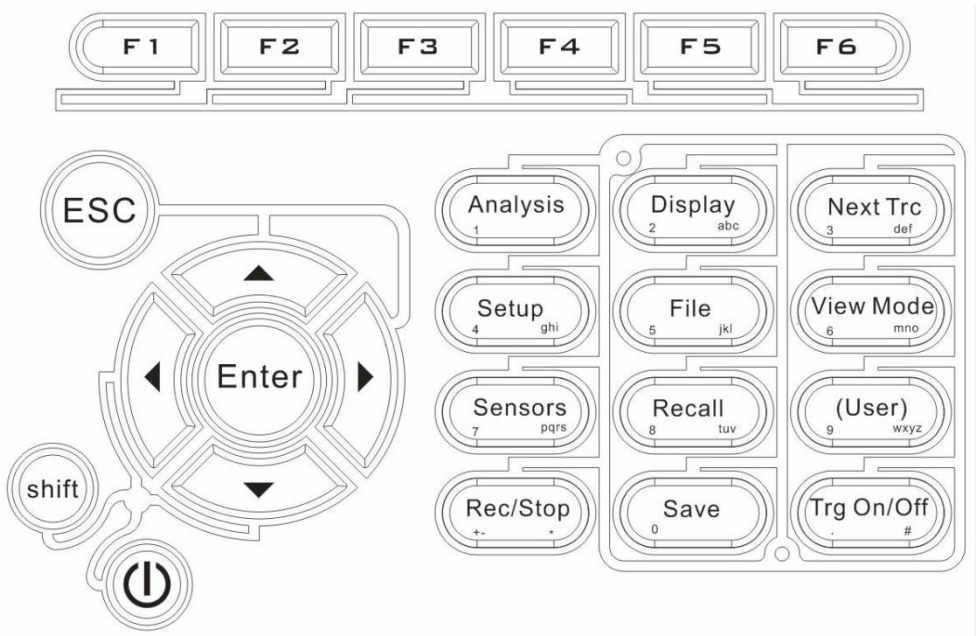
Initially the concept of CSA may appear unconventional to some. However this is the base that provides flexibility and powerful capability to the CoCo-80 and allows each testing case to maintain its simplicity in operation.

3. BASIC COCO-80 OPERATION

This section provides a detailed description of the CoCo-80 device including the user interface, hardware, CSA projects and peripherals.

CoCo-80 User Interface

The CoCo-80 menu-driven user interface is easy to use and requires little training. Hard buttons on the front panel are used to initiate function-specific menus. The buttons are divided into three areas. The **navigation button**s include the power, shift, tab, enter and arrow buttons. The **function buttons** include the Analysis, Display, Setup, File, Rec/Stop and Save buttons. The six **soft buttons** located directly below the display change function depending on the current mode selection.

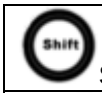
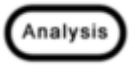
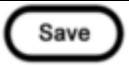
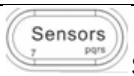


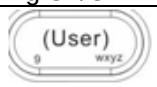
- Figure 4. Button layout on the CoCo-80 front panel.

Summary of Buttons

The following table gives a brief description of the function of the buttons on the CoCo-80.

Button name	Functions
Power	Power on the system Power down the system Reset the system (press it 4 seconds or longer)

 SHIFT	Shift the functions of the arrow buttons or other buttons
Up arrow	Move the focus up In display window scaling, expand the vertical range In display window scaling, vertically move the display range up (depending on SHIFT position)
Down arrow	Move the focus down In display window scaling, reduce the vertical range In display window scaling, vertically move the display range down (depending on SHIFT position)
Left arrow	Move the focus left In display window scaling, reduce the horizontal range In display window scaling, horizontally move the display range left (depending on SHIFT position)
Right arrow	Move the focus right In display window scaling, increase the horizontal range In display window scaling, horizontally move the display range right (depending on SHIFT position)
Enter	Confirm, accept
	Escape: Cancel, or go back to the previous settings, applies to the scaling of display window, cursor position and other operations
 Analysis	Change to analysis screen
Display	Change to the main signal display screen
Setup	Change to the main setup screen
File	Change to the main file view screen
Rec./Stop	Start or stop the time domain data recording designated by the CSA project
 Save	Save the signals that are designated by the CSA project
 Sensors	Open the input channel setup page to configure the sensors or input channels
Recall	Recall or review the last saved signals
Next Trc	Switch to the next display trace

View Mode	Open the View mode menu to set up the view mode for the active trace
Trg On/Off	Turn trigger on or off. When trigger is OFF, it runs in "free run" mode.
 (User)	This button will lead the system to a user previously set CSA and execute it.
F1~F6 function buttons	Context dependent function soft buttons

Status Bar

The Status Bar indicates the status of the system.

- Figure 5. CoCo-80 display Status Bar.

Navigation indicates the name of the screen or provides information about the analysis such as sampling rate.

Volume indicates the volume level for the internal speaker.
Volume for internal speaker (defined in the Setup screen).
Power indicates battery or line power.

Battery status indicates the state of charge or if AC power is connected.

System time displays the time (defined in the Setup screen).

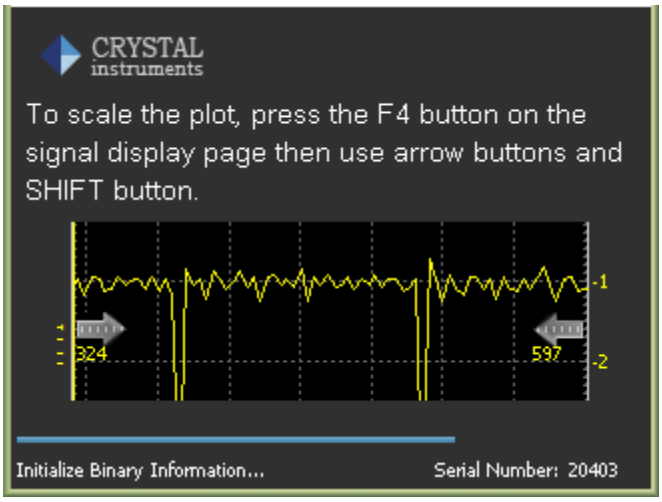
Other status, such as sampling rate, number of averaged frames in spectral processing, number of frames acquired, will be displayed according to installed CSA.

Menu Navigation

The CoCo-80 is operated by moving between screens, entering parameters, and initiating commands with the buttons. This section gives a brief overview of the menu navigation. More detailed information is given in the following sections.

Startup

Press the Power button to power on the unit. The initialization screen shows the startup progress. When the startup sequence is complete the Welcome screen is shown.



■ Figure 6. Startup screen is shown during startup sequence.

Power Down

To power down the unit, press the Power button and then press the Turn Off soft button. The Cancel soft button returns to the previous menu without powering down the unit. Lock keypad function can be selected instead of Power Off.

Arrow Buttons

The arrow buttons are used to move the focus from one field to another on the display. By moving the focus you can select deferent fields to enter parameters, select other screens and enter text. They are also used to zoom in and pan around a trace. When cursors are enabled, arrow buttons are used to move the cursor positions. In the trigger setup window, the arrow buttons can be used to move the threshold and trigger delay.

Enter Button

The Enter Button is used to accept an entry or select an item on the display. In general to select an item use the arrow buttons to move the focus to the item and then press the Enter button to select the item.

Shift Button

The Shift Button serves multiple functions depending on the context. In the signal display window, the F4 soft button ZOOM in/out or moves the display. The Shift Button toggles between ZOOM and move. ZOOM changes the size of the plot and move changes the position of the view.

In the Window setup, if you set a two trace window, the Shift button toggles between the top and bottom traces.

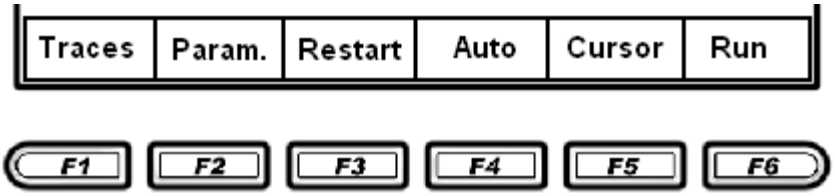
Escape Button

The ESC Button is used to move back to previous screens, or cancel the current action. As the screens are changed using the function or soft buttons, the CoCo-80 remembers the previous screens so that you can easily move back one at time by pressing the Back/Forward button.

Soft Buttons

The F1 – F6 Soft Button functions change depending on which screen is currently shown. Some soft buttons open new screens that include additional soft buttons. To keep the structure clear in the following description the soft button hierarchy will be displayed showing the string of the previous soft buttons or menus in gray and the lowest soft button in black as follows:

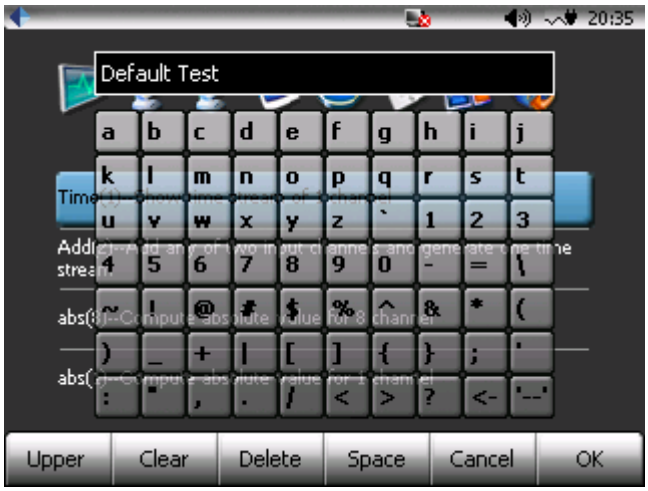
Hard Button Name/Screen Name/Soft Button Name/Screen Name…



- Figure 7. Soft Buttons change function depending on the current screen.

Text and Number Keypad

Several screens require you to enter text using the keypad. When the text keypad is displayed, use the arrow buttons to move the focus to a letter or number and press the Enter button to select the character. When the text entry is complete press the OK soft button.



- Figure 8. Text and numbers can be entered in the input screen.

Text Soft Buttons

Upper/Lower toggles the font to upper or lower case font.

Clear deletes all text from the text field.

Delete deletes the character to the left of the cursor.

Space adds a space.

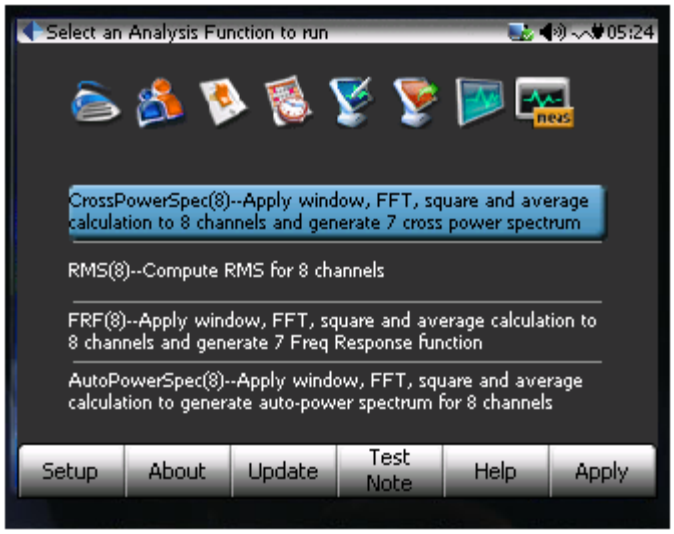
Cancel closes the screen without changing the text.

OK accepts the text and closes the screen.

Note: It is more convenient to use one of 12 hard buttons to enter the number or letters. For example, Button Display can be used to enter number 2 or letter A, B or C. To make the selection, pressing the button quickly will lead the selection to the next one.

Welcome Screen

The Welcome Screen is shown after the system has completed the startup sequence. It shows the available CSA projects at the top and other status at the bottom. It can be used to verify the date and time, network connection settings, add a test note, select a CSA project and run the project.


Select an Analysis Function to run
05:24
CrossPowerSpec(8)--Apply window, FFT, square and average calculation to 8 channels and generate 7 cross power spectrum
RMS(8)--Compute RMS for 8 channels
FRF(8)--Apply window, FFT, square and average calculation to 8 channels and generate 7 Freq Response function
AutoPowerSpec(8)--Apply window, FFT, square and average calculation to generate auto-power spectrum for 8 channels
Setup
About
Update
Test Note
Help
Apply

■ Figure 9. Welcome screen is shown on startup.

Enter Test Note allows you to add text that will be appended to all data files as a file attribute. This is can be used to add notes such as test conditions, locations for later reference and can be used to search through data files by key words. The text typed in the Test Note field will be carried over by the files.

User Information shows the user name and address.

Date and Time indicates the date and time settings of the unit.

Connection indicates the network connection status of the unit.

The CSA project Menu at the top of the screen shows a list of the available CSA projects loaded on the CoCo-80 unit. Use the left and right arrow buttons to select one and press the Run soft button to run the project.

Welcome Soft Buttons

Setup changes to the Setup screen.

About shows the CoCo-80 system information including hardware version, software version, calibration status and software subscription period.

Update connects the CoCo-80 to the CI server via an Internet connection and checks for new files and software updates. You are then prompted to download the updates.

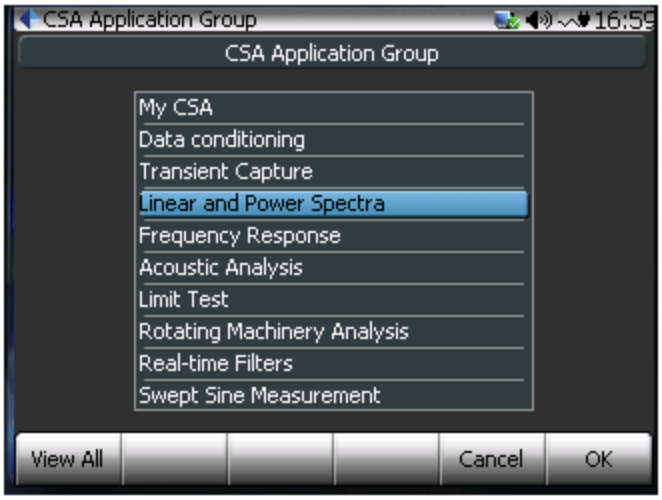
Test Note allows you to enter notes for the test. All data files saved will be attached with Test Note.

Help is the Help document.

Run loads the CSA project and enters into the signal display window.

Analysis Button

The Analysis Button changes the screen to the screen of Configurable Signal Analysis Application Groups.

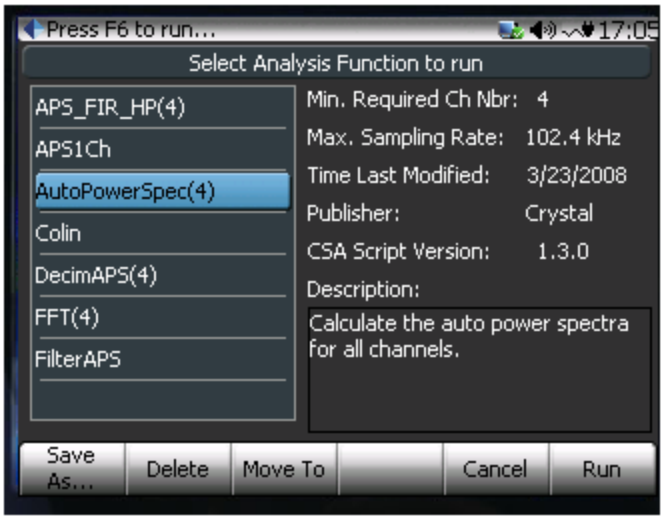


■ Figure 10. CSA Application Groups.

This screen shows several categories of applications. These categories *mostly* match with the template that the CSA uses when it is created with a few exceptions: octave analysis and sound level meter applications are grouped in Acoustic Analysis group. Any CSA with limiting test are grouped in Limit Test group.

After entering one of the application groups, you will see a list of the CSA projects that are loaded on the CoCo-80 in a scroll down menu on the left and information about each project to the right.

Use the up and down arrow buttons to select a project and read the description, maximum sampling rate, time last modified and publisher information on the right. When additional CSA projects are loaded from a PC to the CoCo-80 they will appear on the menu. After selecting one CSA project from the menu press the Run soft Button to load and run the CSA project.



■ Figure 11. Analysis screen is used to select a CSA.

Analysis Soft Buttons

Save As saves the current CSA project with a different name. This can be used to change project parameters and save the new project without overwriting the original project.

Delete removes the CSA project from the CoCo-80 flash memory. The CSA project can be reloaded from the PC if it is accidentally deleted.

Move to lets you move the CSA project file to another group.

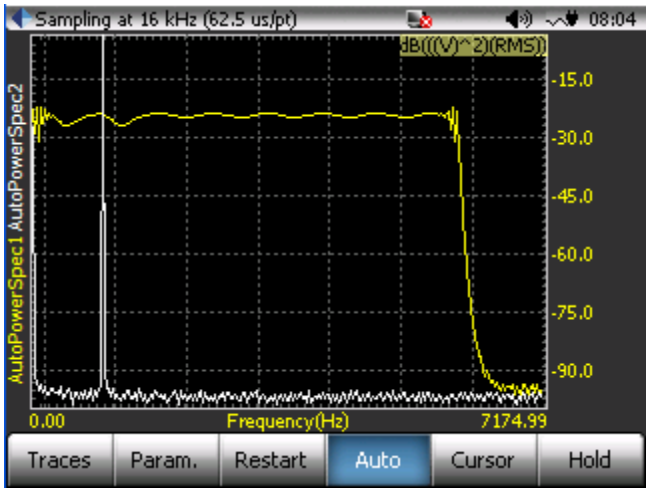
Cancel returns to the previous screen

Run loads the selected project and starts the display. The Enter button also loads and starts the selected project.

Display Button

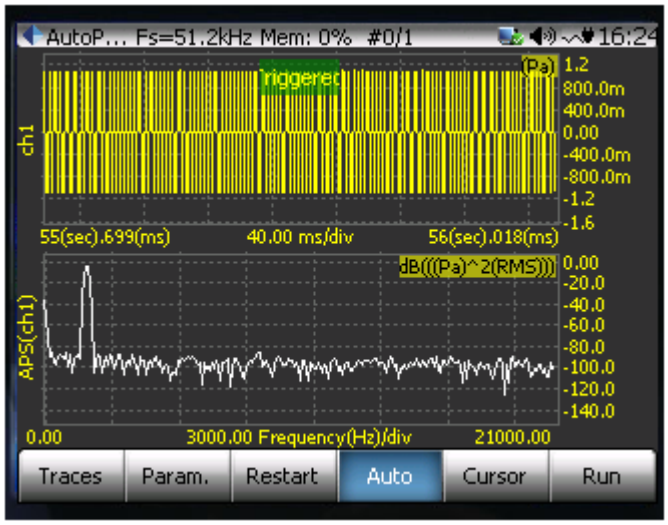
The Display Button changes the screen from the current screen to a center management window for display management. Pressing the Display button and Enter will always lead to displaying the current active window.

The following screen shows the *Signal Display Window*. This is the most frequently used window in this instrument.



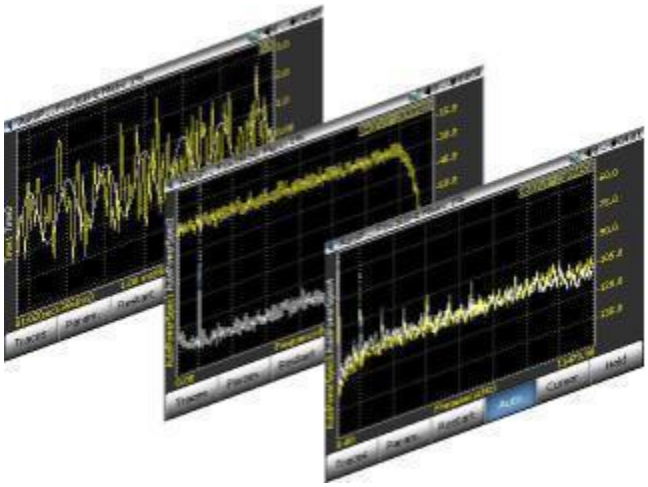
■ Figure 12. Display screen shows a window with one trace.

A signal display window can have either one or two traces. The software allows three types of signal display windows: A window with one trace; a window with top and bottom traces, a window with a 3D waterfall trace. The picture below shows a window with two traces.



■ Figure 13. Two trace window.

A trace is defined as area display with an axis that can show multiple signals of the same dimension such as time or frequency. Only the signals with the same engineering units in X and Y axis can be overlaid.



■ Figure 14. Multiple traces can be defined and multiple signals can be displayed in each trace.

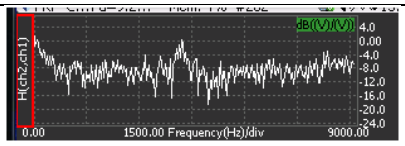
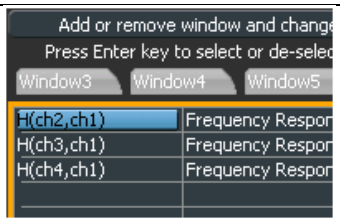
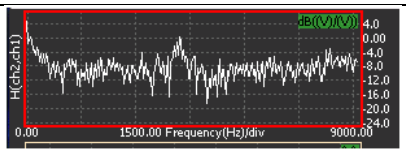
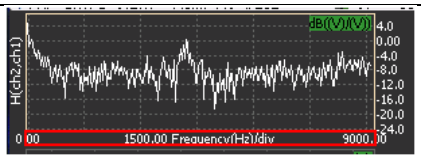
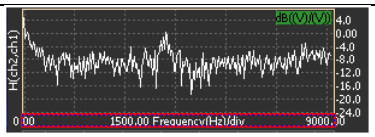
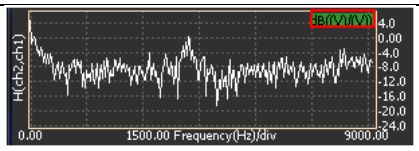
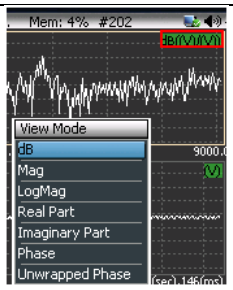
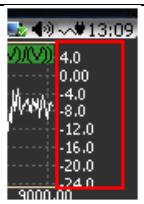
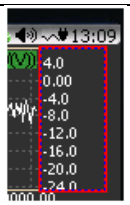
The traces are periodically updated when the Display is in Run mode. To stop the trace updating press the *Hold* soft button. Note that the trace updating display is independent of the Record operation. This means that while traces are update on the display they are not recorded to memory until the Rec./Stop button is pressed. You should understand the difference between the trace update display and the record feature so that errors are not made in recording.

A trace typically consists of five objects:

1. The signal label on the left side (displayed as APS(ch1) in this example)
2. The center display area (the area being highlighted)
3. The view mode (displayed as dB((V)^2(RMS)) in this example)
4. The vertical Y-scale range on the right
5. The horizontal X-Scale range on the bottom

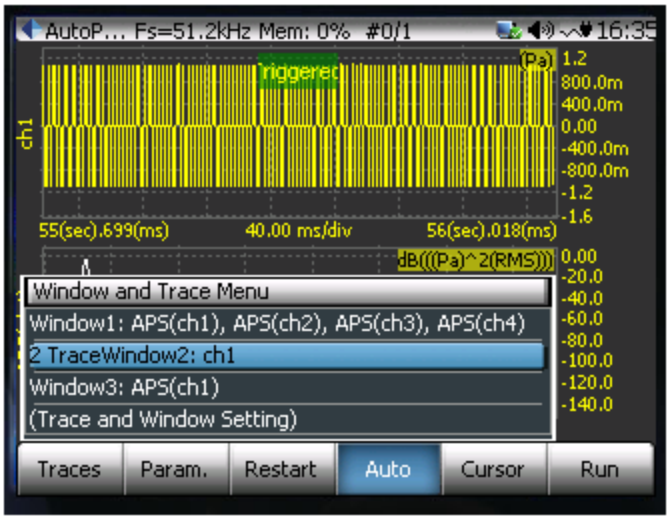
User can move around from one object to another. Once one of the objects is highlighted, pressing Enter button will guide to an operation to set the property of that object. Below is a table describing the corresponding property when Enter button is applied to certain area on the screen:

Highlight Area	After pressing Enter button	Description

		Highlight the Y Label area then press the Enter button. CoCo will show ***Change Signals*** in Trace window
		Highlight the center plot display area then press the Enter button. CoCo will stay in ZOOM mode for a few seconds. Use four arrow buttons to scale the window.
		Highlight the X label area then press the Enter button. CoCo will stay in X scaling mode for a few seconds. Use four arrow buttons to scale the X scale.
		Highlight the Y display unit then press the Enter button. CoCo will let you set the view mode.
		Highlight the Y grid area then press the Enter button. CoCo will stay in X scaling mode for a few seconds. Use four arrow buttons to scale the Y scale.

Signal Display Window/**Traces Soft Button** opens the *Trace and Window Setting* Menu. This menu lists the names of the existing windows in the display and is used to change the windows and signals in the display. The menu lists the defined windows at the top of the menu. The display can be changed from one window to another by selecting a different window from the menu and

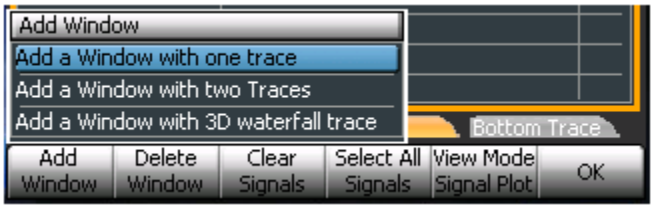
pressing the Enter button. You can define any number of windows to provide a flexible display format.



- Figure 15. Window and Trace Menu.

Signal Display Window/**Traces/Trace and Window Settings Menu** opens the Trace and Window Setting screen. This screen is used to add new windows and define which signals will be included in each trace.

After you select Trace and Window Setting and **Add Window**, you can choose from a single 2D trace, two 2D traces or one waterfall trace.

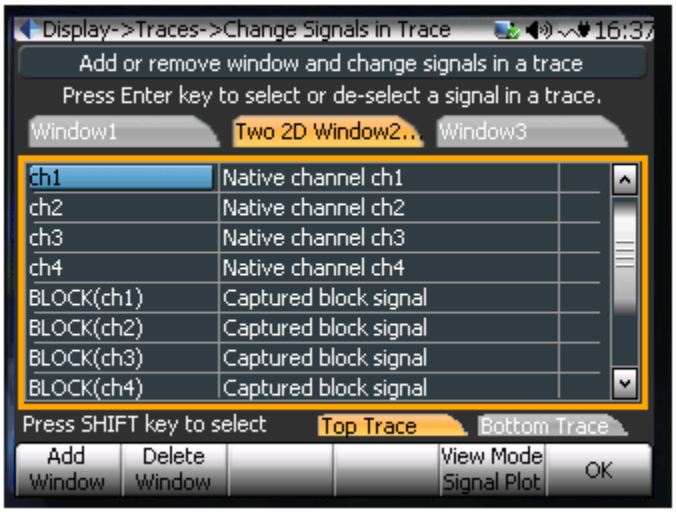


After you select the window type, you need to assign the signals to be displayed in this window. To select a signal press the Enter button to check it. Only signals that are defined in the CSA as display candidates will be visible and can be added to the trace. This feature is designed to simplify the user interface and optimize the CoCo-80 computation resources. If a signal is not available for display then the CSA must be edited before it can be added.

After the first signal is selected, all the signals with different types to the first one will disappear from the list. You can continue to select the rest of the signals which are with the same type as the first one to overlay them.

Set a Window with Two Traces

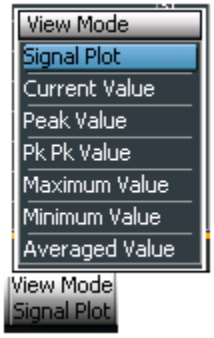
To set up a window with two traces, first select ***Add a Window with two Traces.*** Then the following screen will be displayed:



- Figure 16. Edit window screen is used to add/delete window and add signals to each trace.

In this screen you can set the top and bottom trace by selecting appropriate signals in the same way as you set up the one trace window. **To switch between top and bottom traces within the window, use SHIFT hard key.**

View Mode: The signals can be displayed in either text or graphic plot mode. When it is in the text mode, one of the signatures of the signal must be selected.



- Figure 17 In screen of Trace and Windows Setting different view mode can be selected

Signal Display Window/Traces/Trace and Window Setting Menu/**Signals Displayed in Trace** shows the signals that are attached to the selected trace. Signals can be added to the current trace by selecting them with the arrow buttons and pressing the Enter button to highlight the signal. All highlighted signals are displayed in the current trace. Only signals of the same dimensions can be included in the same trace. For example time and frequency type signals cannot be included in the same trace.

Signal Display Window/Traces/**Trace and Window Setting Menu Soft Buttons**

Add Window creates a new window in the Window List. Windows are named sequentially as Window1, Window2, etc.

Delete Window removed the highlighted window from the Window List.

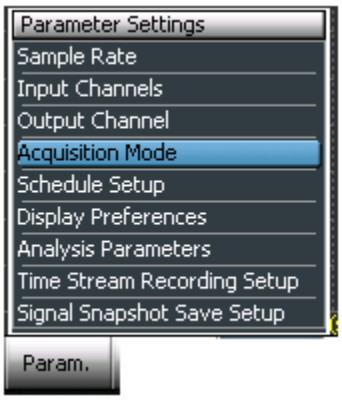
Clear Signals removes all signals from the highlighted trace.

Select All Signals adds all signals to the highlighted trace.

Cancel returns to the previous screen without changing the trace definitions

OK saves the changes to the trace definitions and returns to the previous screen.

Signal Display Window/**Param Soft Button** opens the Parameter Settings Menu. This menu allows you to set parameters for the sample rate, input and output channels, triggering, analysis and time stream recording.



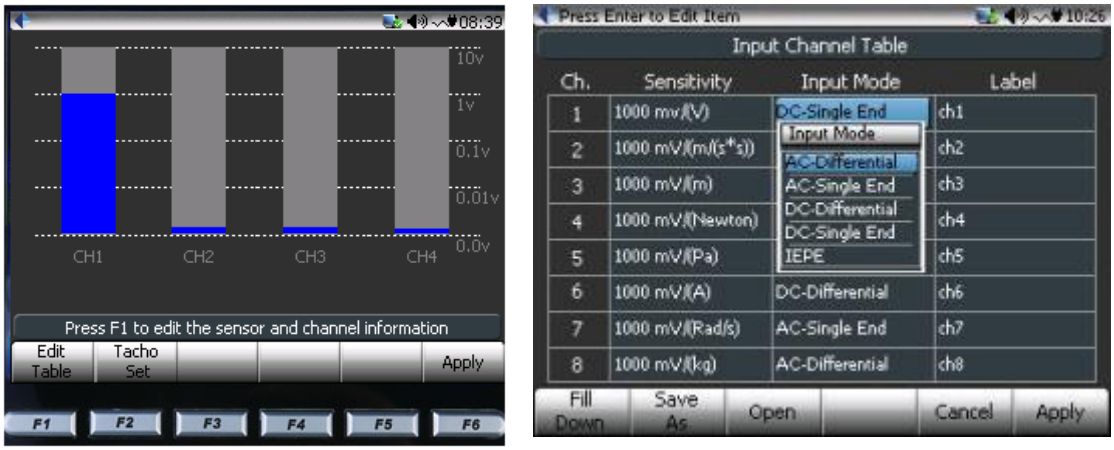
■ Figure 18. Parameter Settings menu.

Signal Display Window/Param Soft Button/**Sample Rate** is used to set the sampling rate for data acquisition. Use the up and down arrow buttons to select from the scroll menu and press the Enter button to accept the setting. Sampling rate is a global setting that applies any loaded CSA.

Signal Display Window/Param Soft Button/**Input Channels** is used to set the sensitivity, input mode and label for the hardware input channels. To edit these parameters use the arrow buttons to select the parameter and press the Enter button. Input Channels is a global setting that applies any loaded CSA.

When the user selects Input Channels menu item, the channel status screen will be shown. It displays the peak magnitude of each channel over a certain period of time. Notice that the vertical scaling of the bars is in logarithmic. The log scaling will help the user see both large and small signals.

Thanks to the high-dynamic technology implemented in the CoCo, as long as the signals are within the full range, the measurement will be reasonably accurate. However if the signals are above the full range, overload will occur and the instrument will flash to warn the user.



- Figure 19 Left: Input status; Right: Input Channel Table

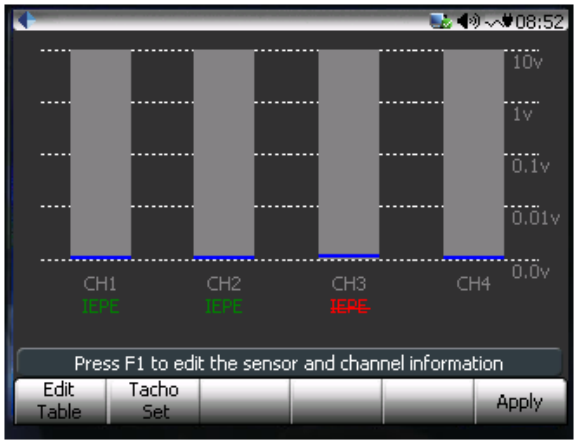
Signal Display Window/Param Soft Button/Input Channel/**Sensitivity** is used to set the physical quantity, units and sensitivity of the input channel. Use the arrow buttons to select the parameter and press the Enter button to select it. The parameters can by applied to all channels using the soft button Apply to all Ch.

Physical Quantity defines the quantity such as acceleration, velocity, displacement, force, voltage, etc.

Units defines the engineering units such as m/s2, cm/s2, gn, etc. for the input channel.

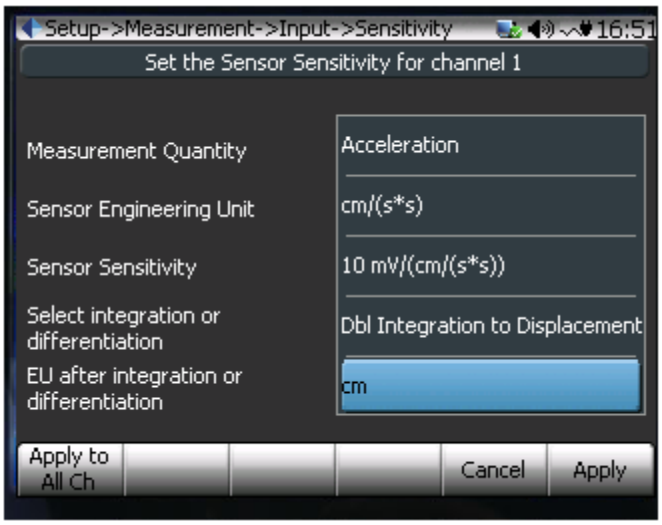
Sensitivity defines the sensitivity in *millivolts/engineering unit* defined in the unit menu. This selection opens a numeric keypad to enter the sensitivity value. Press the OK soft button to accept the value.

When the Physical Quantity is selected as Acceleration, you have the choice to apply a built-in integration or double-integration to generate readings in velocity or displacement. When the Physical Quantity is selected as Velocity, you have the choice to apply integration to displacement. Notice that the algorithms for integration are implemented in the digital domain. They also included a high-pass filter and DC removal routines.



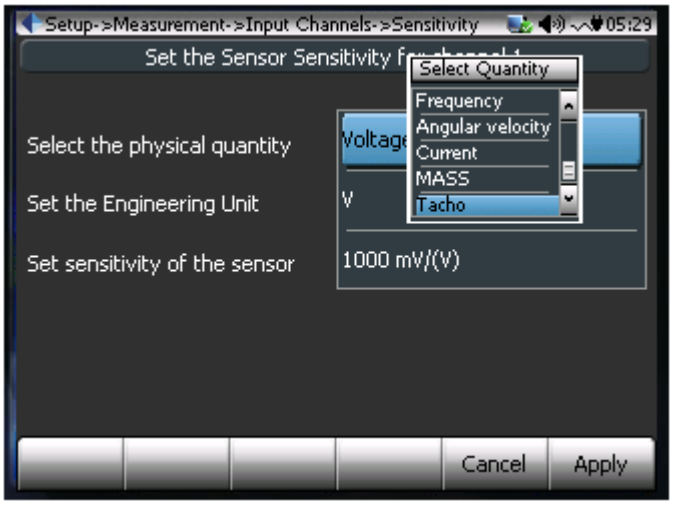
The instrument can automatically detect the status of IEPE sensor connection. If the IEPE type of sensor was not connected correctly, the input channel status will tell.

In the picture above, channel 1, 2 and 3 are enabled with IEPE input mode in software, channel 4 is not. Since channel 1 and 2 are connected with the IEPE sensors, green letters, IEPE, are shown. Channel 3 is not connected to an IEPE sensor therefore IEPE is displayed in red and a crossing line.



■ Figure 20. Apply built-in digital integration or double integration.

Channel 1 is uniquely designed that it can take tacho input. To do so, simply select the Tacho item under the Physical Quantity for channel 1.

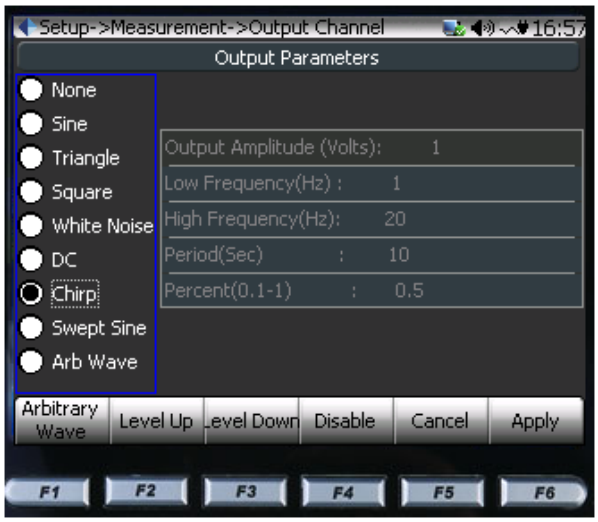


■ Figure 21. Select the Tacho measurement for channel 1.

Signal Display Window/Param Soft Button/Input Channel/**Input Mode** is used to change the input mode. The choices are AC-Differential, AC-Single Ended, DC-Differential, DC-Dingle Ended and IEPE.

Signal Display Window/Param Soft Button/Input Channel/**Label** is used to change the name of the signal. Use the alphanumeric keypad to enter a label name and press the OK soft button to accept it.

Signal Display Window/Param Soft Button/**Output Channel** is used to define the waveform for the output channel. First use the left and right arrow buttons to set the focus. When the focus is set to the left region, you can select one of the signal sources. Use the up/down arrow buttons to select from Sine, Triangle, Square, White Noise, DC, Chirp, Swept Sine or Arbitrary Signal. *None* turns off the output channel. When the focus is set to the right, you can modify the parameters for that particular signal source.

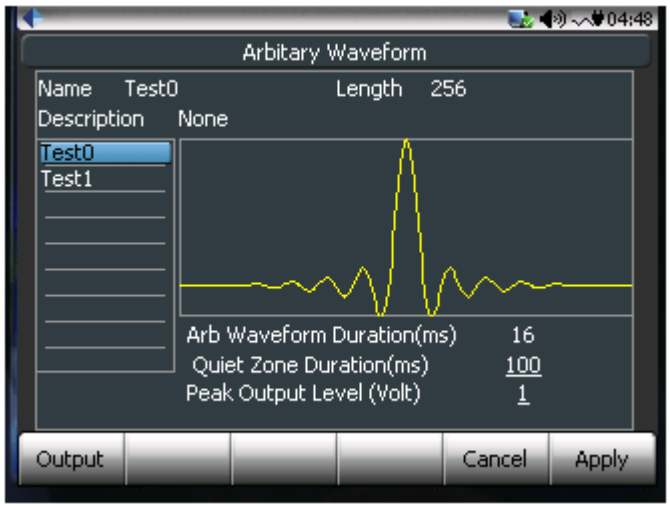


■ Figure 22. Output Channel screen.

For each waveform the parameter settings must also be enters such as range, frequency and amplitude. Output Channel is a global setting that applies any loaded CSA.

Apply saves the settings, activates the output channel and returns to the previous screen.
Cancel discards the settings and returns to the previous screen.

When the *Arb waveform* is selected, you can output an arbitrary waveform file. This file must be uploaded to the CoCo-80 through EDM before it can be used.



■ Figure 23. Arbitrary waveform setup.

In the arbitrary waveform setup, the duration is fixed by the number of points in the arbitrary data file and the sampling rate in use. The Quiet Zone is the time with "zero" output between two arbitrary waveform pulses. The Peak Output Level is the normalized maximum volt for the output waveform. Regardless the value in the arbitrary file, it is always normalized to this peak level volt.

Signal Display Window/Param Soft Button/**Acquisition Mode** is used to configure how the data blocks are captured from the conditioned time streams into the signal analyzer phase. The selections are:

- Free run
- Continuous after trigger
- Single Shot by user
- Single Shot with trigger
- Multiple shots with trigger (auto-rearm)
- Multiple shots with trigger (manual-rearm)

It is important to note that the Acquisition Mode is designed for signal analysis functions only, such as spectrum measurements. The Data conditioning process is not affected by the Acquisition Mode. For example data recording will continue uninterrupted regardless of the Acquisition Mode. Acquisition Mode setting is dependent on the selected CSA.

Signal Display Window/Param Soft Button/**Schedule Setup** is used to configure the automated test.

■ Figure 24. Schedule Setup.

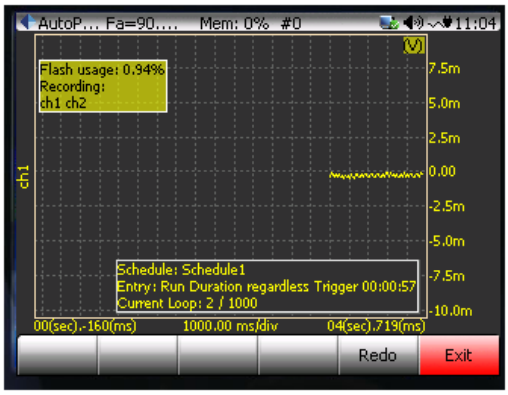
Testing schedule automatically controls the test duration and imitate human operation. Multiple testing schedules can be developed and one is executed at a time. A testing schedule event can include the following events: Loop/End-Loop, Run Duration, Hold, Limit Check on, Limit Check off, Start Recording, Stop Recording, Save Signals, Turn Signal Source On and Turn Signal Source Off.

Activating the testing schedule requires an extra step. This is designed to ensure the test schedule does not start inadvertently. To activate the testing schedule go to the main signal display window and press the Display button for more then 3 seconds then release it. This will activate the test schedule. After the test schedule is activated, all the buttons, except the power button, F5 and F6, will not deactivate because the test is in the automatic mode.

To exit the automated schedule, press F6 the exit button. To redo the schedule, press F5.

Using schedule smartly allows the instrument to divide the total measurement into multiple files. It is easier to retrieve and analyze. The picture below shows a typical schedule with loop/end loop functions. It allows the instrument records 1 hour, stop, run for 1 min, and repeats this recording process 1000 times.

When the schedule is activated, the schedule status will be displayed during the run time.



Use following formula to calculate the total time duration that you can record:

Total Installed Flash Memory in Bytes = (Total Channel Enabled) * (Recording Time in Seconds) * (Sampling Rate) * 8 Bytes * 1.2

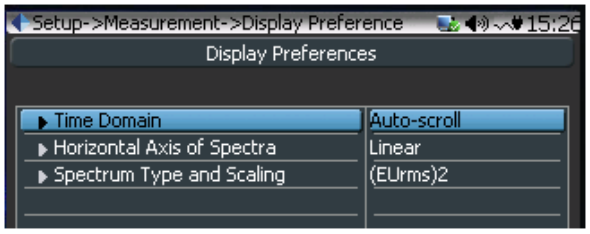
Or

Recording Time in Seconds = Total Installed Memory in Bytes/((Total Channel Enabled) * (Sampling Rate) * 8 Bytes * 1.2)

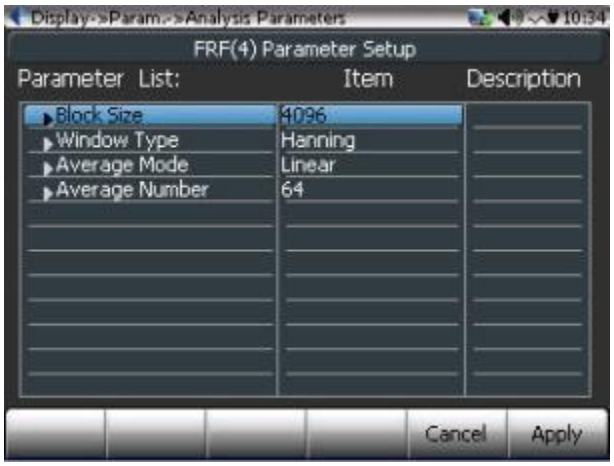
For example if you enabled 6 channels, the sampling rate is 100 Hz with 4GB memory installed:

Recording Time in Seconds = 4GB/(6*100*8*1.2) = 4*1024*1024*1024/(6*100*8*1.2) = 745654 sec (= 207 hours)

Signal Display Window/Param Soft Button/**Display Preference** is used to set up the preferences about signal display. Notice that the spectrum type and horizontal axis, either in linear or log, is set up here.



Signal Display Window/Param Soft Button/**Analysis Parameters** is used to change parameters that are defined in the CSA project. These parameters depend on the definition of the CSA project but may include block size, window type, average mode, average number, excitation and response channel, etc. Refer to the CSA project description in Section 4 for more details. Analysis Parameters setting is dependent on the selected CSA. Different set of CSAs may show completely different Analysis Parameters.

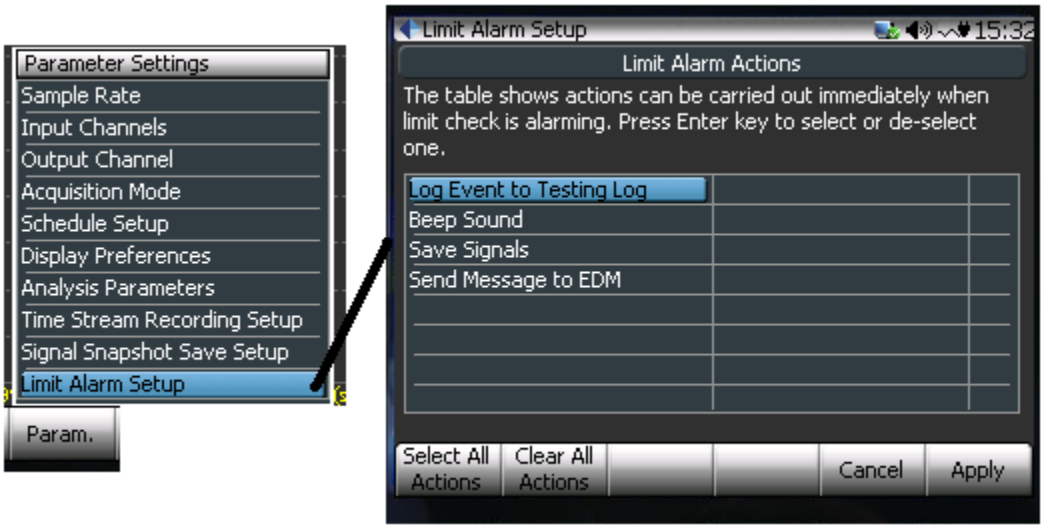


- Figure 25. Analysis parameters setup screen.

Signal Display Window/Param Soft Button/**Time Stream Recording Setup** defines which time streams will be recorded to memory when the Rec./Stop button is pressed. To add a stream to the record list select if in the Signal List using the up and down buttons and press the Enter button. Note that the more signal added to the Record List increases the file size of the recording and reduces the record time to flash memory. Only streams that are of interest should be recorded to conserve memory and maximize recording time. Time Stream Recording Setup is dependent on the selected CSA. Note that only signals that are identified as ***Record Candidates*** in the CSA file will be visible and can be recorded. This feature is designed to simplify the CoCo-80 user interface and optimize the device computation resources.

Signal Display Window/Param Soft Button/**Signal Snapshot Save Setup** defines which signals will be recorded to memory when the Save button is pressed. To add a signal to the record list select if in the Signal List using the up and down buttons and press the Enter button. Signal Snapshot Save Setup is dependent on the selected CSA. Note that only signals that are identified as ***Save Candidates*** in the CSA file will be visible and can be saved. This feature is designed to simplify the CoCo-80 user interface and optimize the device computation resources

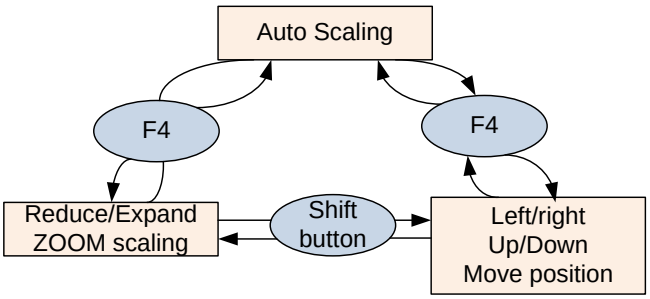
Signal Display Window/Param Soft Button/**Signal Snapshot Save Setup** defines the actions to be taken when testing limit exceeded. Notice that this menu item will only be shown when the CSA project contains limiting check. Usually you won't see this menu entry.



Limit Check Alarm Events include Beep, Screen Flashing, Event Log into Testing Log, Send Message to Host PC, Save Signals.

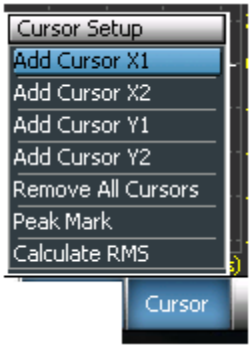
Signal Display Window/**Restart Soft Button** is used to reset the relative time base of the time streams and also reset the averaging and triggering if these features are used in the current CSA project. The *Restart* will be shown as *Control* button in octave analysis, order tracking, swept sine or other advanced software functions. Restart or Control is used to control the running status without re-initializing the project and test.

Signal Display Window/**Auto-Scale/ZOOM/Move Soft Button** controls the vertical scaling of the trace. Auto applies an automatic vertical scaling so that the scale is continuously adjusted to fill the trace. ZOOM scale turns off the automatic scaling and uses the current scale regardless of the magnitude of the signals. When in the ZOOM scaling mode, the four arrow buttons are used for the purpose of reducing or expanding. Pressing the SHIFT button will switch from ZOOM to Move, or Move to ZOOM. When in the Move mode, the four arrow buttons are used for the purpose of repositioning the window. The following diagram further explains the changes in the three different mode of using the navigation buttons:



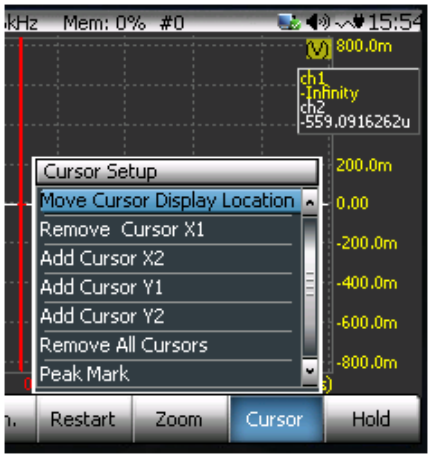
■ Figure 26. Trace navigation buttons.

Signal Display Window/**Cursor Soft Button** adds a vertical cursor to the trace. Use the right and left arrow keys to move the cursor. The signal values are listed to the right for all signals in a trace. Press the Cursor button again to remove the cursor from the trace.



■ Figure 27. Cursors can be added to a trace.

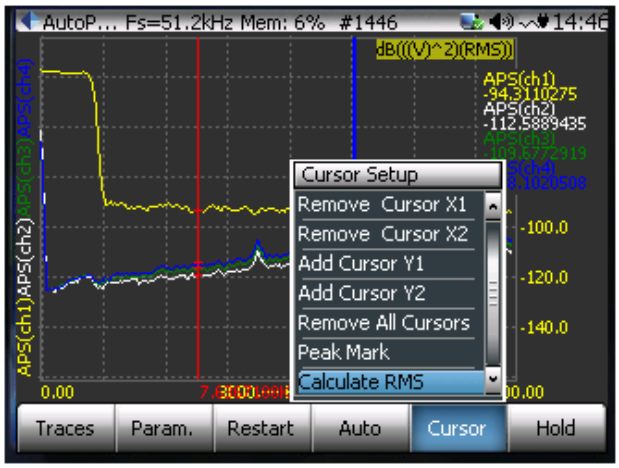
After the cursor is added, you will see a menu item is added to the Cursor Setup menu, Move Cursor Display Location. If you select it, you will be able to move around the square area of displaying the cursor value by using the four navigation buttons. This function is helpful if you feel the cursor display box is not in the right location. Pressing Enter button will fix the cursor display area.



■ Figure 28. Cursor setup.

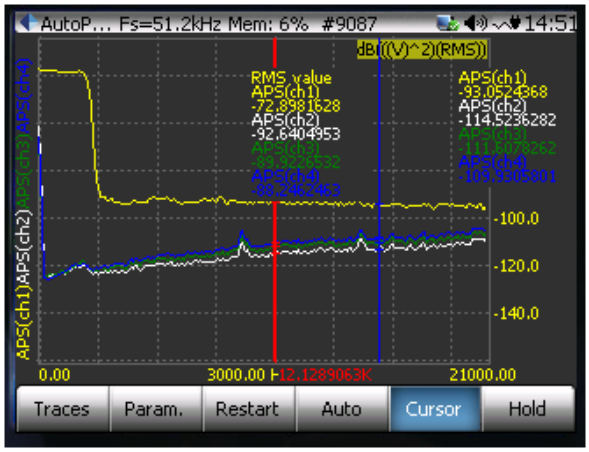
To search for the peak using cursor, simply press the upper arrow button when a cursor is enabled. The cursor will automatically search a peak of the signal in +/- 10% of the horizontal axis area.

Two vertical cursors, two horizontal cursors and a peak mark can be applied. To calculate RMS within a frequency band for auto spectral signals, select *Calculate RMS* menu item:



■ Figure 29. Cursor setup.

The RMS values will be displayed in the same unit as Y label unit. The RMS is estimated to the energy between two vertical cursors.



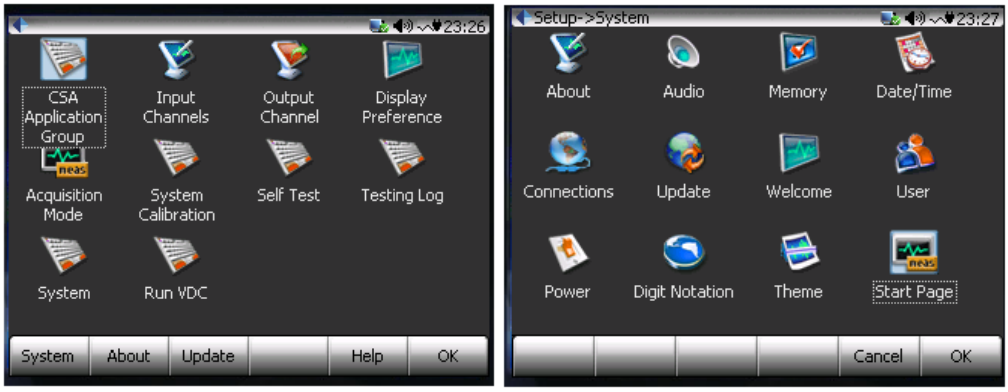
■ Figure 30. Multiple cursor display.

Signal Display Window/**Run-Hold Soft Button** controls the display update and the signal analysis process. When the device is in Run mode the display updates the traces with the signals as fast as possible. When the device is in Hold mode the display stops updating. Note that Run/Hold is independent of Record/Stop. This means that when in Run mode signals are not recorded to memory until the Rec./Stop button is pressed. The record status is indicated by the red record icon blinking at the top of the screen during recording. It is important for you to understand the difference between Run/Hold and Record/Stop so that operator errors are not made in recording signals.

When in Hold mode, the signal analyzer will be held. Processing such as spectral analysis will be frozen.

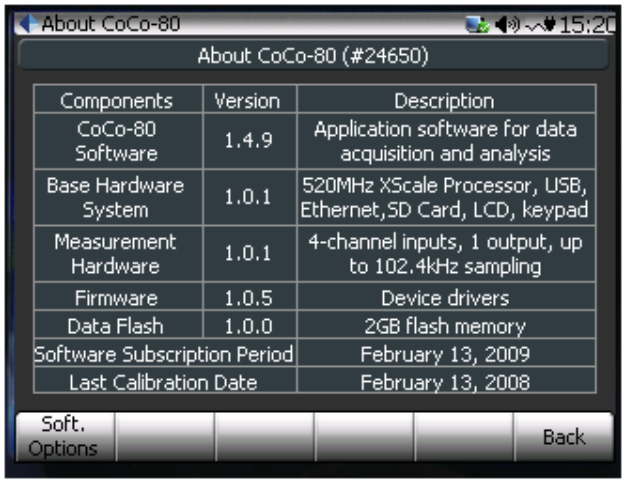
Setup Button

The Setup Button changes the screen to the Main Setup screen. There are two pages of Setup. The first page is all about the measurement settings. Pressing the System icon (F1) will prompt the second page. the second page allows you to change the system parameters including audio, memory, date/time, connection, update, welcome, owner, power, digit notation, theme and measurement settings. Use the arrow buttons to select one of the setting icons and press the Enter button to select it. These settings are described below.



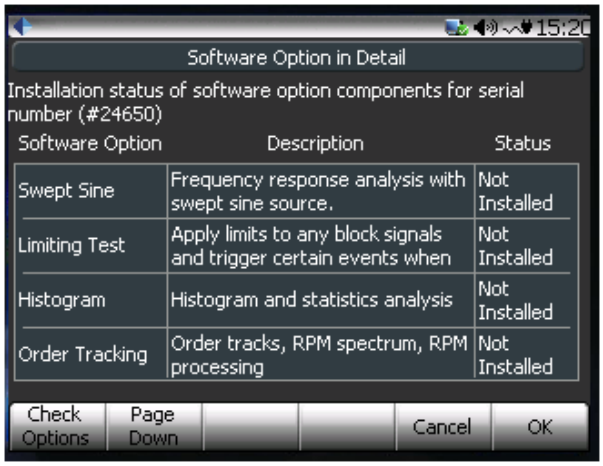
■ Figure 31. Setup Screen

About displays hardware and software version information, software subscription period and calibration status.



■ Figure 32. About Box

Press the F1 Software Option button, the screen will show all installed or uninstalled options.



■ Figure 33. Software Options.

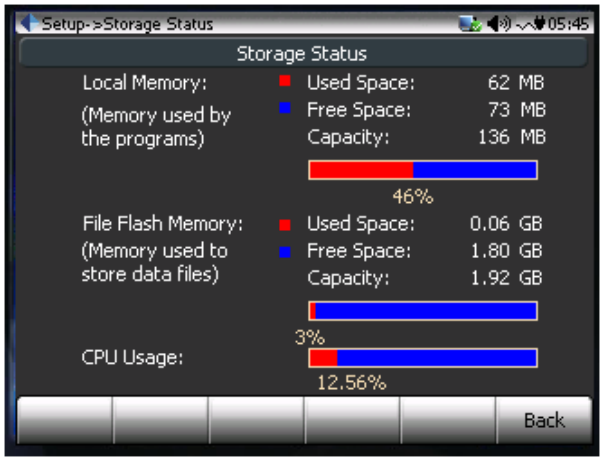
If you press the F1 ***Check Options*** button, the CoCo will check the available software options that can be installed on the remote CI server.

Audio allows you to change the audio feedback settings including keypad, power button and alarm sounds. The speaker volume and microphone level can also be changed. Voice annotation is controlled through Audio setup as well.

■ Figure 34. Audio Settings including Voice Annotation.

Among these settings, the ***Use microphone to record the voice annotation*** and ***Use headphone to listen to any input channel*** are advanced audio functions. User needs to purchase this software option to enable such setting.

Memory displays the status of the CoCo-80 memory. This includes local memory used by the CoCo-80 software and the flash memory used to store recorded data. This display can be used to monitor the remaining flash memory remaining during field operations. When flash memory is full then the data must be downloaded to the PC and removed from the CoCo-80 before more data can be recorded.



■ Figure 35. Memory and DSP CPU usage.

Date/Time allows you to enter the current date and time so that this information can be included as a file attribute with the data files.

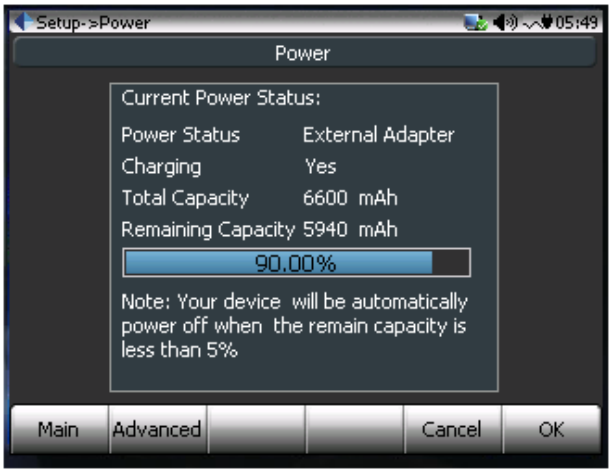
Connections displays the status of the Ethernet, USB Client or Wireless connections. The IP Setup soft button allows you to specify a fixed IP address or to use DHCP.

Update allows the CoCo-80 to check for new software components on the Crystal Instruments server and conduct online software updates at the user's request. CoCo-80 must be connected to the Internet using Ethernet or wireless when on-line update is performed

Welcome shows the welcome screen that lists the available CSA projects loaded on the CoCo-80 and other status.

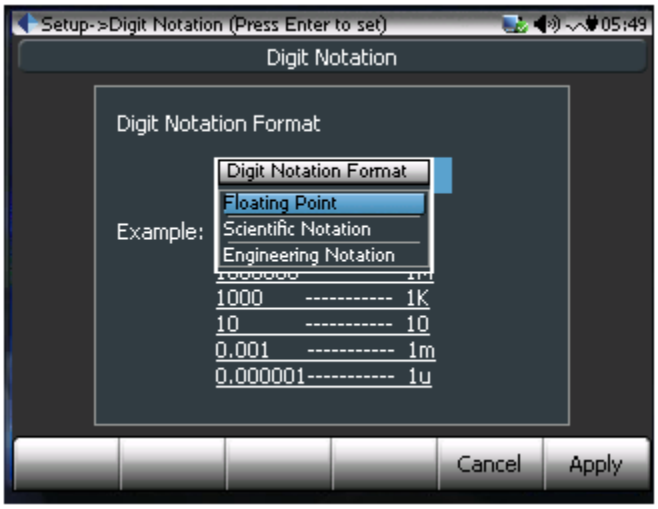
User shows the information recorded for the user of the hardware including Name, company, address, telephone and Email and appends the information as an attribute to all data files. This information can be edited by selecting it with the arrow buttons and pressing the Enter button.

Power indicates the status of the power including the Remaining capacity of the battery. The Advanced soft button allows you to customize the power settings to optimize the battery life for specific conditions including Automatic mode which maximized the battery life by automatically turning off the LCD and the backlight and Ethernet. Maximum Active Mode keeps all components on but uses the maximum power consumption.



■ Figure 36. Power Status Screen.

Digit Notation is used to change the format that numbers are displayed on the CoCo-80. The choices include: Floating Point, Scientific or Engineering notation.



■ Figure 37. Digit Notation Settings.

Theme changes the display from black to white background.

■ Figure 38. Theme Settings: Black or White Style.

Measurement Page shows the Measurement Settings including Input, Output, Display Preference, Acquisition Mode, System Calibration, Self Test and Testing Log.

■ Figure 39. Setup/Measurement Screen shows the Input, Output, Display and Acquisition Mode settings.

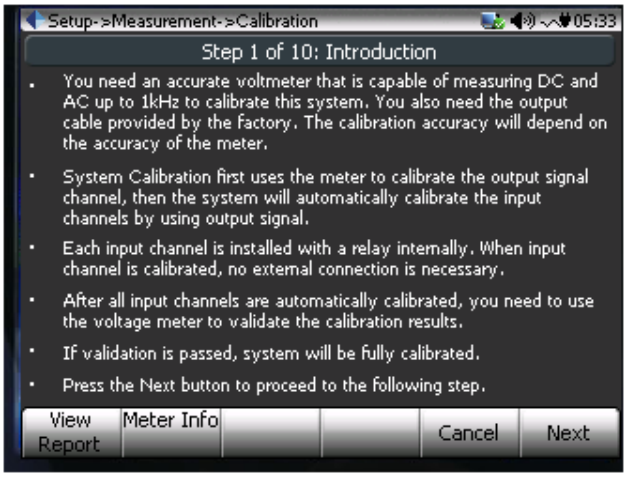
Setup/**CSA Application Group** is the same as pressing Analysis button.

Setup/**Input Channels** changes the display to the Input Channel Table. This is described above under the Analysis/Parameters section.

Setup/**Output Channel** changes the display to the Output Parameter screen. This is described above under the Analysis/Parameters section.

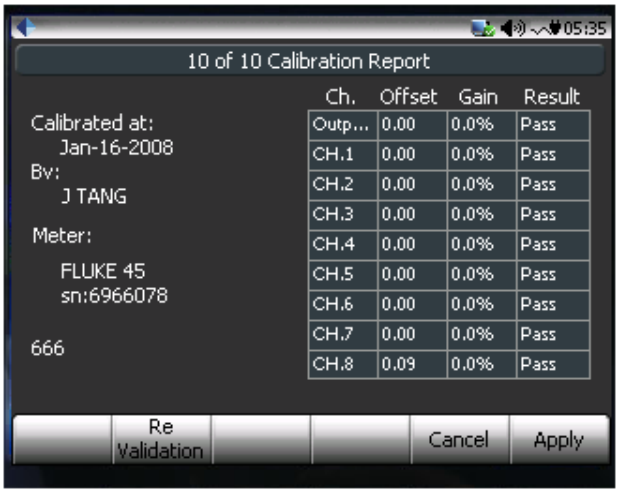
Setup/**System Calibration** is used to calibrate the input and output channels. This procedure requires a high precision calibrated AC/DC volt meter. CI recommends that this task is performed by the factory or designated companies that are familiar with the calibration process.

The picture below shows one of the ten steps to conduct the calibration. It will take about 10 minutes to complete a calibration.


Setup->Measurement->Calibration
05:33
Step 1 of 10: Introduction
You need an accurate voltmeter that is capable of measuring DC and AC up to 1kHz to calibrate this system. You also need the output cable provided by the factory. The calibration accuracy will depend on the accuracy of the meter.
System Calibration first uses the meter to calibrate the output signal channel, then the system will automatically calibrate the input channels by using output signal.
Each input channel is installed with a relay internally. When input channel is calibrated, no external connection is necessary.
After all input channels are automatically calibrated, you need to use the voltage meter to validate the calibration results.
If validation is passed, system will be fully calibrated.
Press the Next button to proceed to the following step.
View Report
Meter Info
Cancel
Next

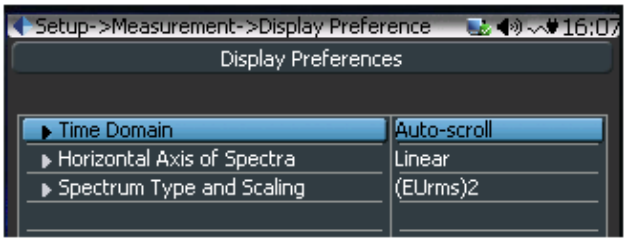
■ Figure 40. System Calibration Screen.

Calibration results can be viewed on the CoCo-80 by pressing View Report in the above screen.



■ Figure 41. Calibration Report.

Setup/**Display Preference** changes to the Signal Display Preferences that are applied to all traces.



■ Figure 42. Display Preference screen.

Setup/**Time Domain** Block, Scroll or Auto-scroll. The block display option displays one block of data when the buffer is filled. After a buffer is displayed, the system will grab another buffer a fast as possible for the next block display. Some portion of time signals between buffers will be ignored for display. The scrolling display shows data scrolling continuously on the screen like a strip chart with no gaps in the scrolling display. The auto-scrolling option enables the system to choose the best display method for the user defined horizontal time interval. Usually if the total time interval is less than 0.5sec, it is displayed one block at a time as in block mode while a longer time interval will let the system display the signals with the scrolling method.

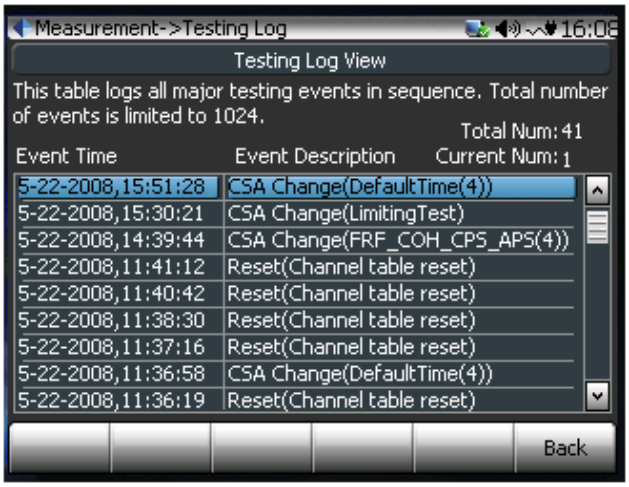
Horizontal Axis of Spectra specifies the format of the horizontal axis of spectra as either linear or log scale.

Spectrum Type and Scaling specifies the vertical scaling for spectrum traces. The choices include: $(EUrms)^2$, EUpeak, EUrms, and $(EU)^2/Hz$. This selection only affects the auto-power spectra or linear FFT spectra.

Setup/**Acquisition Mode** Soft Button specifies the trigger settings including free run, continuous after trigger, single shot without trigger, single shot with trigger (manual re-arm trigger), or automatic re-arm.

Setup/**Self Test** Soft Button allows you to run a self test for the hardware without using external meter. A built-in precision signal source is used to check whether the input channels are in the reasonable range. If the circuitry of any channel is damaged or goes out of range, the Self Test will tell. Self Test does not change or replace the last time calibration results.

Setup/**Testing Log** record the most recent activities happens to the measurement. A sample of testing log is show below.



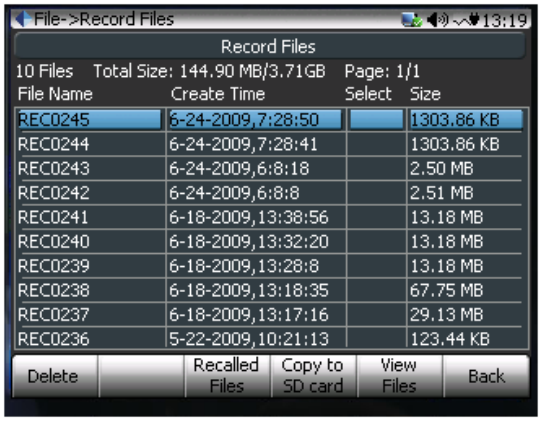
- Figure 43. Test Log View.

Setup/**Run VDC** icon will allow you to switch to the vibration data collector mode. If your CoCo is not installed with VDC mode, this icon will not be effective.

File Button

The File hard button displays the Storage Capacity status including capacity, used space and free space. Also the number of files is listed including CSA files and measurement data files.

File/**Files** displays a list of all the record files including the name, created time, test note and size.



- Figure 44. Record Files screen shows the names and other attributes of files stored on the CoCo-80.

Delete->Delete Newest allows you to delete the newest a few files including and after the file that is being highlighted from the flash memory. For example if there are 4 files in order in the

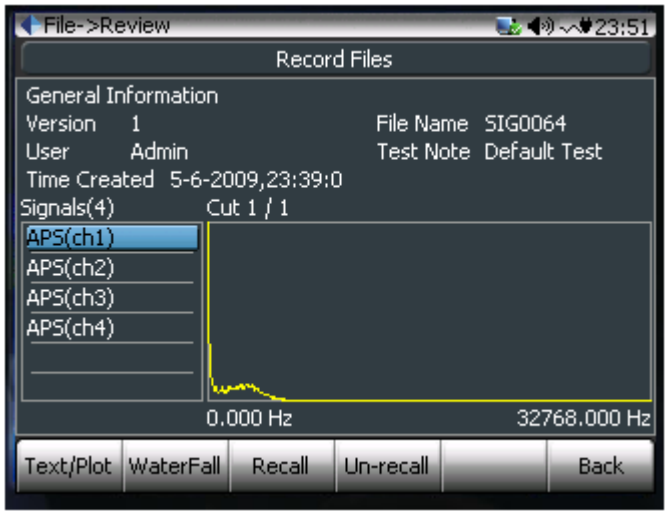
list, File4, File3, File2 and File1 where File4 the latest and File2 is being highlighted, when Delete Newest is pressed, File4, File3 and File2 will be removed.

Delete->Delete All allows you to delete all files for the flash memory at once.

Copy to SD Cards allows the user copying the signals or recording files into the SD memory card.

Recalled Files allows the user viewing all the recalled signal files. Recall is a useful operation to review the data files in a signal display trace.

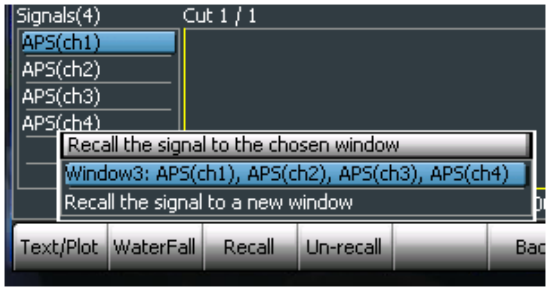
View Files shows a summary of the data file. The Text/Plot soft button allows you to display a text view including type, points, sample rate and units or change to a low resolution of the time record.



■ Figure 45. View the file content per signal.

Once a signal file is opened, the user can show it in text mode or plot mode. this is for the purpose of simple preview. To view the signals in the display plot trace, please use the recall function.

To recall a signal, press the F3 recall button:



The CoCo will allow the user to recall a signal into an existing trace, or a new trace. Recalling into existing trace will overplot this signal with the all existing ones with the same type.

Rec./Stop Button

The CoCo-80 combines two traditional instruments, a data recorder and a signal analyzer into one hardware platform. Due to the requirement of different use cases, the user interface design is a bit unconventional. Two hard buttons, Rec./Stop and Save are designed for storage; two soft buttons, Restart and Run/Hold are designed for controlling the data processing flow.

For details please refer to later Chapter about saving data.

Save Button

The Save Button is used to save block signals to memory. These include transient time signals and spectra signals, which unlike time stream data are a snapshot of a single block of data at the time the Save button is pressed. This can be used to capture averaged spectra or transient events at any time. You can choose which signals are saved when you press the Save Button by selecting **Signal Snapshot Save Setup** under the Param. Button.

When the CoCo-80 is connected to a PC the saved block signals can be downloaded using the EDM software.

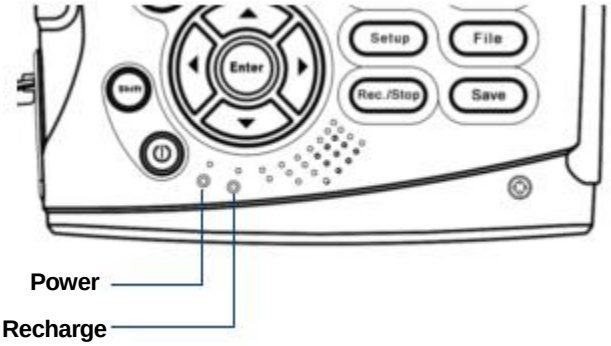
CoCo-80 Startup and Shutdown

This section describes power on and off, lock the keypad and how to reset the CoCo-80.

Power on and off the CoCo-80

The power button is located at the lower-left corner on the keypad. The very first time the CoCo-80 is used, it is necessary to set the clock time. All the data acquired and stored will include the clock time as a file attribute with a clock time accuracy of seconds.

There are two LEDs on the front panel. The one on the left close to the power button is an indicator for the system *on* or *off*. When the system is turned on, it will be lit red. The LED on the right is the indicator for external power charging. When the CoCo-80 is being charged, it will be lit in red. When the system is fully charged and still connected to the external DC power, it will be lit in green.



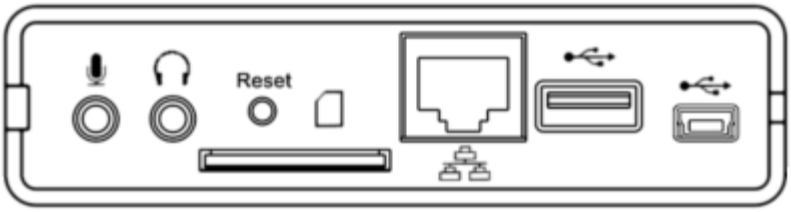
■ Figure 46. Two LEDs showing power and recharge status.

System Reset

In the rare event of a system lock up the power on/off button may not respond. To restore the unit you can reset the system in one of two ways.

Reset the system by Pushing the Reset Pin

You can reset the system by inserting a pin or paper clip through the reset hole. The Reset pin hole is shown below.



■ Figure 47. Reset pin hole can be used to shutdown the CoCo-80.

Reset the system using the Power Button

You can reset the system by pressing the power button for more than 4 seconds which will force the system to shut down. After the system is shut down, it can be rebooted by pressing the power button again.

CoCo-80 Software Disaster Recovery through EDM

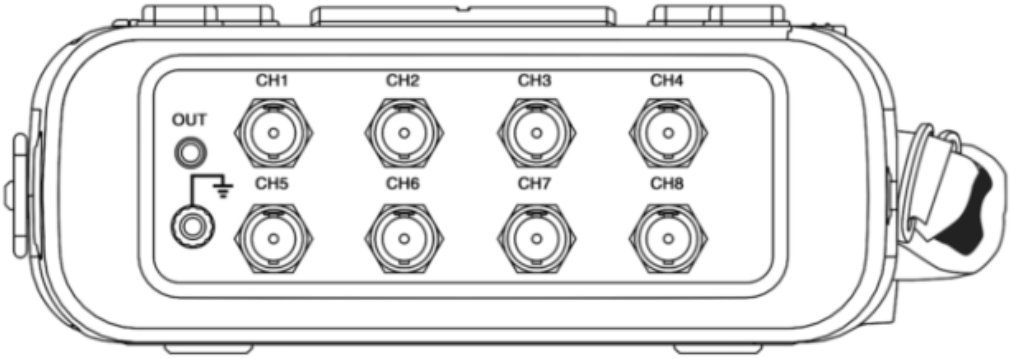
In the case that the CoCo-80 application software programs are completely corrupted due to an unknown reason, you can also use EDM, the host software, to restore the CoCo-80 back to its original state when CoCo-80 is connected to the host via USB.

Keypad Lock

To avoid accidental mistaken operation to the keypad, it can be locked by pressing the power button and then pressing the Lock the Keypad Soft Button. To do this, simply press the Power button and make the second selection.

CoCo-80 Input Connections

This section describes the CoCo-80 input connections and the related circuit design including a description of single ended versus double ended AC versus DC coupling and IEPE.



- Figure 48. BNC input connectors, output and ground connector.

System Calibration

The CoCo-80 loads factory calibration data during start-up, eliminating the need for daily calibration checks. Although the CoCo-80 does not require daily field calibration, CI recommends an annual calibration and performance verification by local CI service centers.

To execute the System Calibration, first press the Setup hard button, then select System Calibration icon and press the Enter button.

DC-Differential

DC-Differential allows measurement of signals with a non-zero mean, DC component and uses differential input mode. Non-zero mean signals are typically low frequency signals or signals that are measured relative to ground. Differential mode is recommended when measuring signals with a common mode voltage (CMV). CMV is an in-phase signal that appears simultaneously on both input terminals of an input channel. Provided the sum of the signal and the CMV do not saturate

the input and cause clipping, the measurement will be accurate. If the signal and CMV exceed the input range then the signal will be clipped and produce erroneous results. If the signal and CMV are very high and exceeds the maximum over-voltage rating of the instrument front end then the data will be erroneous and the hardware can be damaged. This must be avoided to protect the hardware from permanent damage.

DC-Single End

DC-Single End allows measurement of signals with a non-zero mean, DC component and uses single ended input mode. Single ended mode is recommended for most cases and when no CMV exists. This is the case when measuring the output of sensor amplifiers. A CMV will produce noise in single ended mode.

AC-Differential

AC-Differential applies a low frequency high-pass filter to the input filtering the DC component of the signal. The result is a zero mean signal. This is most commonly used for dynamic signals with CMV.

AC-Single End

AC-Single End mode combines the AC filter with single ended mode. This is most commonly used for dynamic signals with no CMV such as measuring the output of an amplifier.

IEPE (ICP)

The CoCo-80 supports IEPE constant current output type for its input channels. The built-in circuit is powered by a 4mA constant current source at roughly 21 Volts. IEPE refers to a type of transducer that is packaged with a built-in current source. IEPE is an acronym for ***Integral Electronic Piezoelectric***. IEPE requires an AC filter so DC measurements are not possible when IEPE is enabled. CoCo has a cut-off frequency of 0.3Hz@-3dB for the IEPE input mode.

CoCo can automatically detect the IEPE sensor connection when the IEPE input mode is enabled. The sensor indication is shown in following three modes:

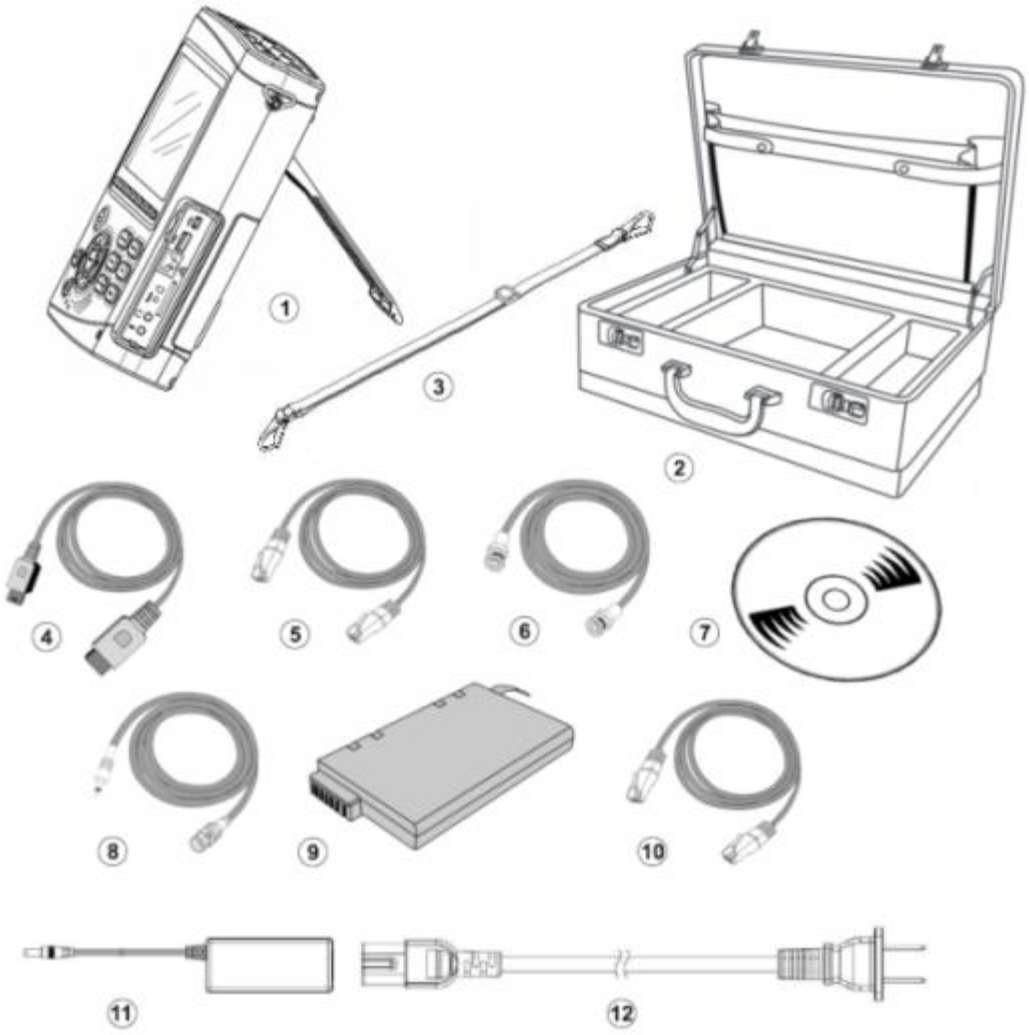
A green IEPE sign indicates that the IEPE is set in the channel table and the IEPE sensor is detected; a red IEPE sign indicates that the IEPE mode is set in the channel table but the sensor has not been detected. This is a faulty mode; the empty space means that this channel is not set to IEPE.

CoCo-80 Output Connections

The CoCo-80 includes one output channel that can act as a function generator and provides a variety of waveforms synchronized with the input channel sampling rate. The output channel is a 0.3 mm stereo jack. A stereo jack to BNC adaptor is provided with the unit. For each waveform the parameters such as amplitude and frequency can be specified with the Output Parameters screen from the Display screen and the Param. soft button. The output waveforms include: None, Sine, Triangle, Square, White Noise, DC, Chirp, and Swept Sine.

CoCo-80 Peripherals and Accessories

This section describes the peripherals and accessories available on the CoCo-80 including SD Card, audio devices, Ethernet, USB, audio and battery. The CoCo-80 includes interfaces to many peripheral devices. These can be connected to the hardware via the connectors shown below.



■ Figure 49. CoCo-80 Peripherals and Accessories.

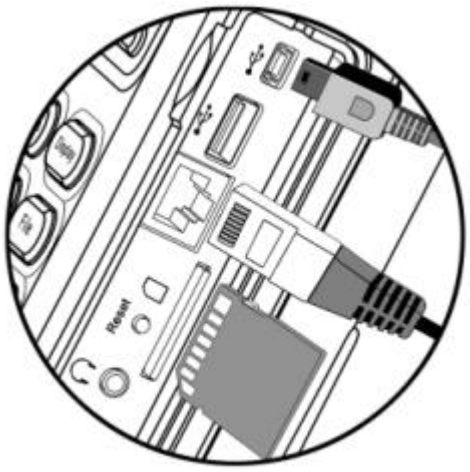
Item Description:

#	Description
1	CoCo-80 Handheld Data Acquisition System
2	Suitcase with foam inside
3	Hang Strap
4	USB cable
5	Regular Ethernet cable
6	BNC cable
7	CD for EDM, the host software, User's Manual in PDF
8	Cable for Output (Signal Source)
9	Main Battery (installed)
10	Cross-Over Ethernet Cable
11	AC/DC Power Adapter
12	Power Cable to AC Outlet

- Figure 50. CoCo-80 peripheral connections.

Ethernet

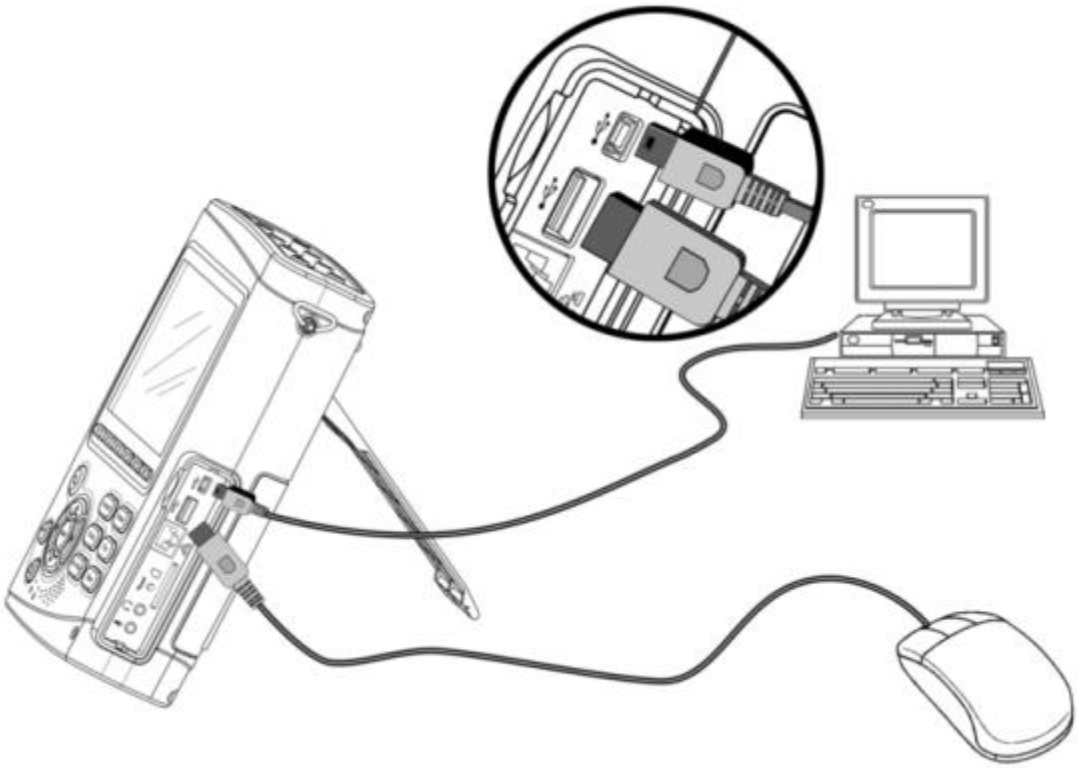
CoCo is equipped with an RJ 45 - 100 BaseT Ethernet jack to connect to a local area network or directly to a PC. A cross-over Ethernet cable must be used to connect the CoCo-80 to a PC **directly**. If CoCo is connected to a network hub, router or a switch, then a regular Ethernet cable (not a crossover cable) should be used.



- Figure 51. Ethernet connection.

USB Ports

The CoCo-80 has two USB ports, one USB-client (mini-USB) and one USB-host (type A). They are fully compliant with USB 2.0 full speed specification and backward compatible with USB 1.1. The shapes of two ports are different, as shown below:



■ Figure 52. CoCo-80 has two USB ports: client for PC connection and host for peripheral connection.

The USB-client port is used to establish communication between the CoCo-80 and a PC. When the USB-client port is used, CoCo-80 device acts as a slave unit.

The USB-host port is used to establish communication between the CoCo-80 and other USB-based peripherals, such as a USB-mouse, or a USB memory stick. In this case, the CoCo-80 acts as a USB master device.

Mouse Support

USB Mouse is supported with following operations: F1~F6 function buttons, two virtual keypads, scrolling and make selections in any combo box, ZOOM-in scaling, ZOOM-out scaling the graph.

To ZOOM-in the graph, hold the left button of the mouse and drag to the area that you intent, then release the left button.

To ZOOM-out the graph to the previous scaling stage, double-click on the graph.

SD Card Interface

The MMC/SD-Card interface is designed to be used for multiple purposes, mainly the high density memory card. The official information about the MMC/SD-card can be found on the official site: http://www.sdcard.org/

The user can copy the recorded signal files from the internal flash memory to SD memory card or directly record the time stream data to SD memory card.

Audio Devices

CoCo-80 has the following built-in audio devices:

- 3.5mm stereo jack connector for an earphone
- Built-in speaker
- Built-in microphone

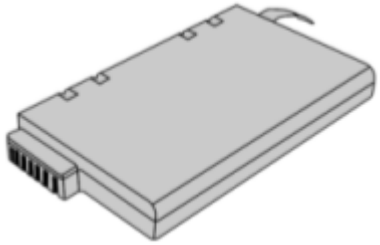
The earphone and speaker are used to generate status sounds that provide audio feedback to the use such as:

- AC adapter is connected
- AC adapter power was disconnected
- System boot-up successful
- System boot-up failure

Battery

There are two batteries inside the CoCo-80 device, the clock battery and the main battery. The clock battery is only used maintain power to the internal clock. It is located inside the hardware and should be replaced when necessary by an authorized CI service center and should not be replaced by the user. The main battery is used to power the instrument. The main battery is a Lithium-Ion type cell with a capacity of up to 6600 milliamp-hours. The main battery is located inside the enclosure and can be replaced by opening the lid on the back of the CoCo-80.

To recharge the main battery, simply connect the AC adaptor between the CoCo-80 and the AC power source. The power source must be in the range of 100 - 250 VAC. When the CoCo-80 is turned on, a battery capacity symbol is shown on the status bar that indicates the state of charge of the battery.



- Figure 53. CoCo Battery.

Battery Charger

This is an optional accessory. This charger can charge the main battery without using CoCo. It is convenient to use this charger to charge an extra main battery while one is in use. This charger is designed and made by Crystal Instruments.

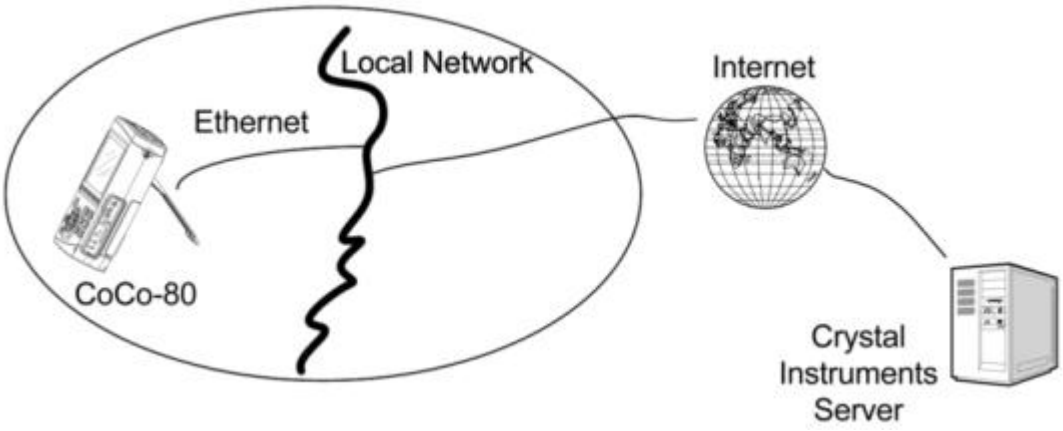
DC/DC Converter for Car Cigarette

This is a DC-DC adapter using automobile cigarette lighter, voltage isolated. Input: 9~30VDC. Output 15V/3A (±10%).

With this converter, the user can use the power from the car cigarette adapter to support the CoCo.

CoCo-80 On-Line Updates

The CoCo-80 application software has the capability to check for software updates from the CI web server when you connect the CoCo-80 device to the Internet. You first connect the CoCo-80 to a local network using regular Ethernet. After you connect it, press Setup button and click the Update icon. The CoCo-80 will first check the connection status, and then a connection will be established.



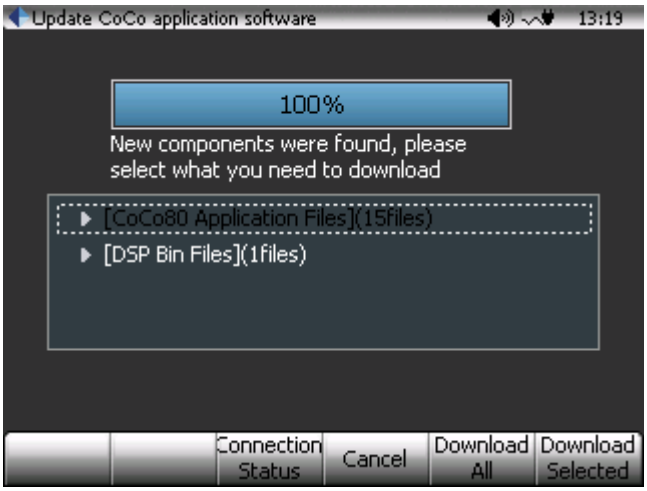
■ Figure 54. Network connection for CoCo-80 update.

After communication is established, the CoCo-80 will check with the server to verify if the software subscription is valid. If the CoCo-80 is in the valid software subscription period, it will then check the latest software components available on the server and download them to the CoCo-80 after the user's approval.

Two types of software components can be updated:

- CoCo-80 application software
- CSA projects

The CoCo-80 user interface will always ask the user's confirmation before the software is downloaded. When the new CoCo-80 application software is downloaded, you will be asked to confirm to overwrite the old version with the new version. Then the older version will be overwritten.



■ Figure 55. On-line update detection status screen.

When new CSA projects are downloaded, if the new CSA files take the same file name as the old ones, the old CSA files will be renamed to the CSA files with sequence number added. This approach will prevent overwriting the old CSA files that may have been changed by the user.

If the connection to the Internet could not be established, please press the Setup button and click on the Connections icon. This will lead you to the Ethernet network setup. The most common problem is caused by inappropriate IP address setting. Most often, your LAN requires you set up the IP as "Dynamically obtain an IP via DHCP". Please refer to section "Configuring the CoCo-80 Network Settings" in this manual for more details.

Advanced Audio Functions

CoCo-2, CoCo-80 and CoCo-90 are all equipped with advanced audio functions. These audio functions allow you to listen to the vibration or any measurement quantity or record voice annotations during signal recording. This document describes how to use the audio functions.

The advanced audio features can be summarized as following:

- You can listen to any measurement input using headphones without interrupting the measurement or recording process.
- The audio monitoring is automatically scaled to the listening range and the headphone audio can be manually adjusted.
- You can record voice annotations at any time and length during time stream recording.
- A customized microphone is available with a push button to control voice annotation recording.
- Voice annotations can be replayed on the CoCo hardware through headphones.
- Voice annotations are attached to each recorded file, and can be played back on the PC using the EDM software
- CoCo can play back any recorded time streams using its output port. The output port can drive another audio device such as headphones or external speakers.

These advanced audio functions require the following minimum hardware and software versions: CoCo Software Version ≥ 1.7.8; Base Hardware System Version ≥2.0.9; Measurement Hardware Version ≥ 10.1.0; Firmware Version ≥ 1.5.0.

Hardware Audio Peripherals

Three hardware audio peripherals are used for the advanced audio functions:

1. Internal Speaker
2. External Headphone
3. External Microphone

The internal speaker is used to generate system-related signals, such as the sound simulating the key press, power-on/off or alarm. Voice annotations and measurement input audio can only be played back through headphones and not through the internal speaker.

- Figure 56 Built-in Speaker

The external headphone jack uses the 3.5mm stereo jack connector. You can connect any headphone to this connector.

- Figure 57 An example of headphone

The headphone jack is located at the second to the left with a headphone symbol. Voice annotations and measured input audio can be played back through the headphones.

■ Figure 58 Connectors

The external microphone must be ordered from CI. It is designed so that when the microphone button is pushed, the voice annotation recording is activated. The microphone jack connector is on the left side of the peripheral panel. Do not use any microphone other than the specified CI microphone because without the microphone button hardware, you will not be able to start a voice annotation recording.

■ Figure 59 Microphone with push button (part # CoCo-A12)

Audio Functions

The audio functions are controlled through the CoCo, Setup->Audio Setup screen.

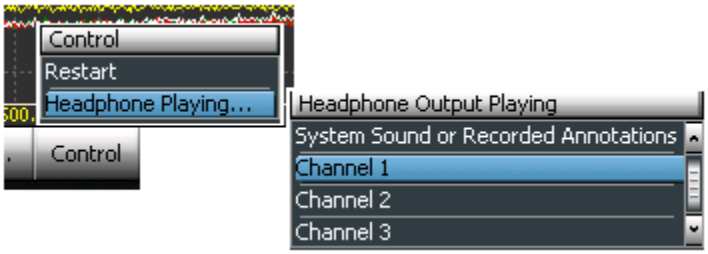
■ Figure 60 Audio Setting page

Keypad Sound: Enable and select the internal speaker sound output when any of the buttons are pressed.

Power Button Sound: Enable and select the internal speaker sound output when the power button is pressed.
Alarm Sound: Enable and select the internal speaker sound output for system alarms.
Use microphone to record the voice annotation: Enable the external microphone recording function. When this item is checked and the user presses the connected microphone button, the voice annotation is recorded until the button is released. Multiple annotations can be recorded during a measurement. If this item is not checked, the microphone button will not activate any voice recording.
Use headphone to listen to any input channel: Enable the external headphone listening function.

Headphone Listening

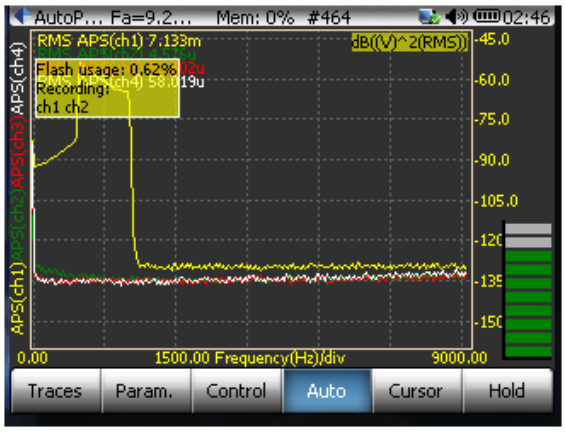
When "Use headphone to listen to any input channel" is enabled, under the F3 Control Button of the signal display screen, you will see the Headphone Playing menu item. Select one of the input channels. If you do not want to listen to the input channels, then set the selection to "System Sound or Recorded Annotations."



■ Figure 61 Select the Channel for Headphone Listening

Record Voice Annotations

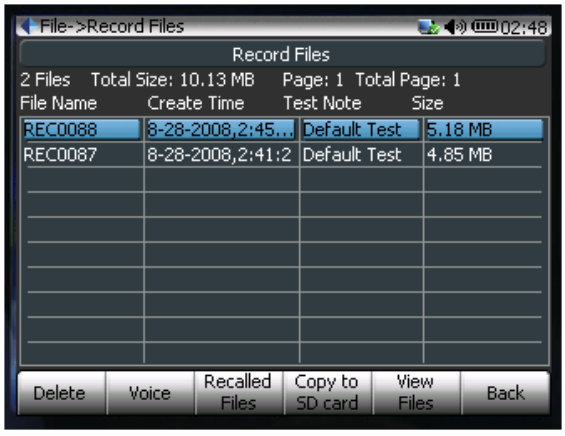
After "Use microphone to record the voice annotation" is checked in the audio setup, connect the external microphone (Part #CoCo-A12) to the microphone jack. Press the Rec/Stop button to record the time signals. While the time signals are being recorded, you can press the microphone button to record your voice annotation. The voice annotations will be attached to the recorded time streams. The green bar on the right bottom corner on the screen indicates the volume of the signal received by the microphone.



■ Figure 62 Monitor the volume of the microphone input

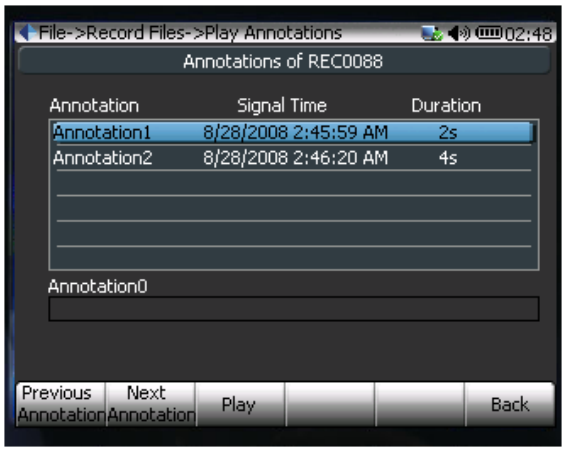
Playback the Voice Annotations on CoCo

To play back the voice annotation, first press the File button, then the F1 Files, then the F2 Voice button.



■ Figure 63. Play back voice annotations from the File View.

The F3 Play button allows you to hear the previously recorded voice annotation. Then you can use the F1 Previous Annotation or F2 Next Annotation Buttons to play all the annotations. If the Voice button is not shown, it means the signal file saved has no voice annotation attached.

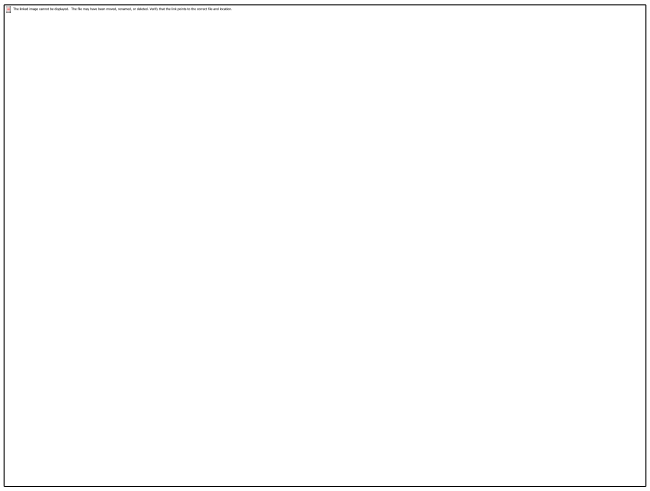


- Figure 64. Play all annotations using Next and Previous buttons.

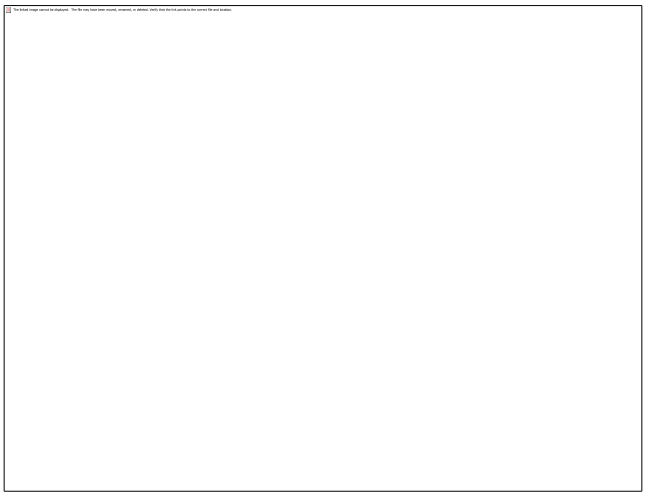
Voice annotations will be listed under each recorded or saved signal files and can be played back with EDM PC software.

Playback the recorded signals from output channel

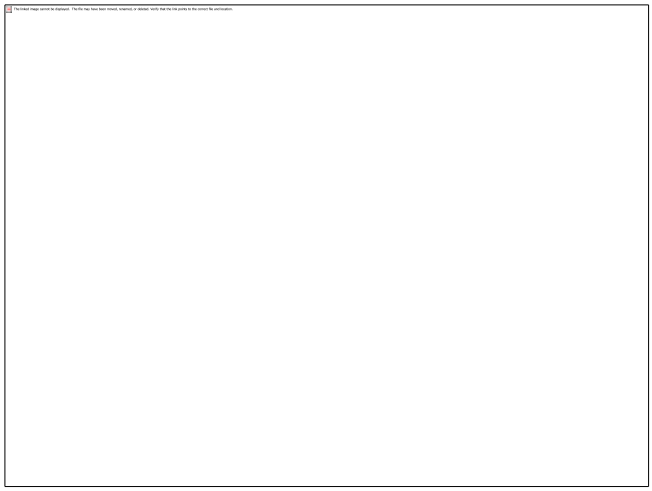
The CoCo can playback any of the recorded signals from its output channel. To do so, open a recorded file and press F5 the Playback button.



If the user made voice annotations while the time stream is recorded, the voice annotations will be played back as well.



After the signal playback is finished, the screen will show a message of ***Waveform playback finished.***



Notice that the recorded signal will be played back at the sampling speed of when it was acquired. Inside CoCo, the A/D converters and D/A converter share the same sampling clock. Due to this design, when the signal is played back, input signal cannot be analyzed.

CSA — Configurable Signal Analysis

This section describes the Configurable Signal Analysis concept that is the basis for the CoCo-80 functionality and allows advanced users to customize the analysis features to suit individual needs. This section gives a brief description that is intended for the basic user. It does not describe writing projects for advanced users. For more on writing CoCo-80 analysis functions refer to the manual about CSA Editor that comes with EDM host software.

When the CoCo-80 powers up the Welcome screen is shown. From this screen the use must select one of the CSA projects loaded on the CoCo-80. When a CSA project is selected, the project defines the settings and analysis functions that are computed by the CoCo-80. These settings include the following:

- Parameters used by the data conditioning functions such as Add, Subtract, Multiply, Divide, Square, Square Root, RMS, Scale, Offset, Decimate
- Parameters used by the signal analyzer functions such as FFT, Auto Power Spec, Coherence, FRF
- Time Stream Data Recording Settings
- Block Data Save Settings
- Trace Settings

The CSA is designed to control how the data is processed, not how the data is acquired. When the CSA is changed, the processing functions are changed according to the new CSA, but the data acquisition parameters do not change. For this reason, the following settings have global effect and are not part of CSA project:

- Sampling Rate
- Input Channels: sensitivity, coupling, channel labels
- Output Channel: output waveform settings

All pre-programmed CSA projects have predefined parameters that are loaded when the project is selected. You can modify the parameters on the CoCo-80 from the ***Param*** Soft Button in the Display screen. Modified CSA projects can be saved with a different name using the Save As soft Button in the Analysis screen so that the original projects are not overwritten.

Most pre-programmed CSA projects carry a variable called *Maximum Sampling Rate*. This is the sampling rate that this CSA can safely execute without exceeding its computational resource limit. Maximum Sampling Rate is used to limit the selection of the sampling rates.

Preprogrammed CSA projects

The CoCo-80 is preprogrammed with a set of default CSA projects which provide a wide range of options that meet most users' needs. Additional CSA projects may be downloaded from the Crystal Instruments web site. In addition, by using CSA Editor the advanced users may edit or develop their own customized CSA projects to meet their specialized needs. Typical default CSA projects are given below.

- Table 1. Preprogrammed CSA project Descriptions. Yellow-highlighted are most often used

CSA Group	CSAs used for 4-channel CoCo-80	CSAs used for 8-channel CoCo-80	Description
Data Conditioning	RMS(4).csa	RMS(8).csa	Calculate the RMS of each input channel. Overlap ratio and average time are changeable.
	Time(4).csa	Time(8).csa	Apply no data conditioning for any channel. Only show the native input channels.
	PkPk(4).csa	PkPk(8).csa	Calculate the peak-to-peak value for each channel.
	Subtract(4).csa	Subtract(8).csa	Channel 1 is subtracted from each other channel.
	Multiply(4).csa	Multiply(8).csa	Multiply each channel by channel 1.
	Add(4).csa	Add(8).csa	Add channel 1 to other channels.
	Integration(4).csa	Integration(8).csa	Digitally integrate each channel. Suitable for signals with higher frequency content.
	IntegrationLow(4).csa	IntegrationLow(8).csa	Digitally integrate each channel. Suitable for signals with low frequency content.
	OffsetScale(4).csa	OffsetScale(8).csa	Apply an offset and a multiplier to each channel. The offset and multiplier can be modified in Analysis Parameters.
Transient Capture	Transient(4).csa	Transient(8).csa	Time streams from each channel are captured into block signals by enabling Acquisition Mode.
	Capture1Ch(4).csa	Capture1Ch(8).csa	Block-capture the channel 1 with up to 64k buffer size
Linear and Power Spectra	AutoPowerSpec(4).csa	AutoPowerSpec(8).csa	Transform the time streams into block signals then apply data window and FFT to calculate auto power spectra. FRF/Coh will not be calculated.
	APS1Ch(4).csa	APS1Ch(8).csa	Only calculate the auto spectrum for 1 channel with up to 64K buffer size
	FFT(4).csa	FFT(8).csa	Transform the time streams into block signals then apply data window and FFT.

Frequency Response	FRF(4).csa	FRF(8).csa	Calculate the frequency responses when channel 1 set as reference and the others as responses.
	CrossPowerSpec(4).csa	CrossPowerSpec(8).csa	Calculate the cross power spectra when channel 1 set as reference and the others as responses.
	FRF_COH(4).csa	FRF_COH(8).csa	Calculate the FRF and coherence when channel 1 set as reference and the others as responses.
	FRF_COH_CPS_APS(4).csa	FRF_COH_CPS_APS(5).csa	Calculate the FRF, cross-power, auto-spectra and coherence functions when channel 1 set as reference and the others as responses.
Real-time Digital Filter	DecimFltr(4).csa	DecimFltr(6).csa	Apply n stage of 2:1 decimation to each input channel to obtain the signals with lower sample rate.
	FIR(4).csa	FIR(8).csa	Apply FIR Low Pass, High Pass, Band Pass, and Band Stop filters with filter length 67.
	RemezFltr(4).csa	RemezFltr(8).csa	Apply Remez FIR Low Pass, High Pass, Band Pass, and Band Stop filters with filter length 67.
	IIRFltr(4).csa	IIRFltr(8).csa	Apply IIR Butterworth Low Pass, Butterworth High Pass, Chebyshev Band Pass, and Elliptic Band Stop filters with filter order 7.
Acoustic Analysis	OCT(4).csa	OCT(8).csa	Apply 1/1, 1/3, 1/6 or 1/12 octave filters to time streams and generate octave spectra and filter r.m.s. time traces. It conforms to ANSI std. S1.11:2004 and IEC 61260-1995.
	OCT RPM(4).csa	OCT RPM(8).csa	Apply 1/1, 1/3, 1/6 or 1/12 octave filters to time streams and generate octave spectra and filter RPM traces. It conforms to ANSI std. S1.11:2004 and IEC 61260-1995.
	SLM(4).csa	SLM(8).csa	Sound Level Meter (SLM) template provides various overall sound level readings, time and frequency weighting according to IEC 61672-2002.
	SLM RPM(4).csa	SLM RPM(8).csa	Sound Level Meter (SLM) template provides various overall sound level readings, time and frequency weighting according to IEC 61672-2002.
Order Tracking	ORDTRK(4).csa	ORDTRK(8).csa	Normalized Order Spectra and Order Tracks
	ORDTRK(4)_CFS.csa	ORDTRK(8)_CFS.csa	Constant Frequency Bands
	ORDTRK(4)_Phase.csa	ORDTRK(8)_Phase.csa	Order Tracks with Phase

LimitTest	TimeLimiting(4).csa	TimeLimiting(8).csa	Apply limit test to the time stream signal of each channel. Limits are edited in CSA Editor.
	APSLimiting(4).csa	APSLimiting(8).csa	Apply limit test to the auto power spectrum of each channel. Limits are edited in CSA Editor.
	Transient_Limit(4).csa	Transient_Limit(8).csa	Apply the limit test to transient captured signals. Limits are edited in CSA Editor.
My CSA	Histogram(4).csa	Histogram(8).csa	View Histogram and statistical analysis of each channel.

When a CSA project is running you can choose to display, record or save data streams or signals.

Change CSA projects from the CoCo-80

A CSA project specifies the analysis settings and functions including: analysis parameters and functions, time stream recording, block data save and trace settings. After a CSA is selected it can be modified from the CoCo-80 to change these parameters using the ***Traces*** and ***Param*** soft buttons in the Display screen. The modified CSA can then be saved using the Save As soft button in the Analysis screen. This allows modified CSAs to be saved and used again later.

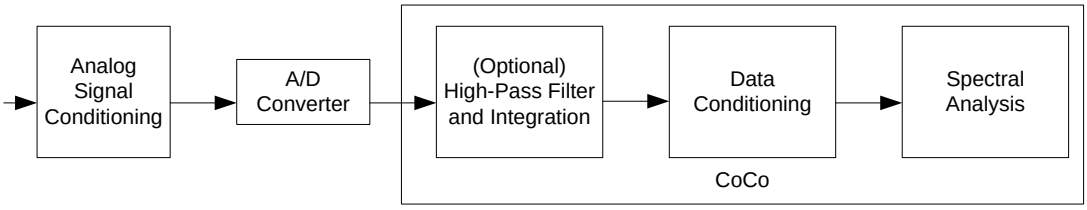
Editing CSA from the EDM Software

CSA files can also be edited or new CSA files can be created from scratch from the EDM software on a PC. This feature allows the advanced end user to create custom analysis functions to suit their special needs. This advanced topic is not covered in this manual. Refer to the CI Support web page for documentation about editing CSA from the EDM software.

To initiate the CSA Editor, click on the CSA Editor icon on the upper-left corner of EDM.

The Analog Signal Conditioning and Data Pre-Conditioning

In a global picture, the signals will go through the following stages in an analyzer:



First the analog signals will be processed by the analog signal conditioning circuitry. It usually includes an input mode selection logic, the high-pass filter for AC coupling and constant current source for IEPE. Then the analog signals will be digitized simultaneously by multiple A/D converters. The digital signals coming out of A/D converters, after a unique calibration process, will be fed into the DSP chip inside of the CoCo box.

The CoCo may first turn on a pre-data conditioning algorithm. This pre-data conditioning algorithm may apply the high-pass filters so to reduce the DC drift, or convert the acceleration signals into velocity or displacement. It will also apply the appropriate engineering unit setting to the input signals.

Then the data streams will be fed into a user controlled Data Conditioning module, and then spectral analysis. This part will be explained in detail in the next section.

The Data Processing Flow of CoCo

CoCo-80 combines two instruments, a data recorder, and a signal analyzer into one system. It is important to understand the differences between these two functions. The following sections provide details of each.

The data conditioning and recording phase includes processing the data from native acquisition channels and data conditioning. Data conditioning operations include +-*/, filtering, integration, differentiation, calibration and other math operations that can be applied to the continuous time streams. All the signals in the data conditioning and recording stage are continuous time streams with a fixed sampling rate and do not include any gaps. Time streams can be displayed or recorded.

The signal analyzer phase includes Acquisition Mode, and CSA based block-by-block processing. The acquisition mode controls how the continuous time streams are captured in fixed block size records. The processing phase applies algorithms such as spectral analysis to the block-by-block signals. Figure 65 shows how the input data is processed in the data conditioning and signal analyzer phases.

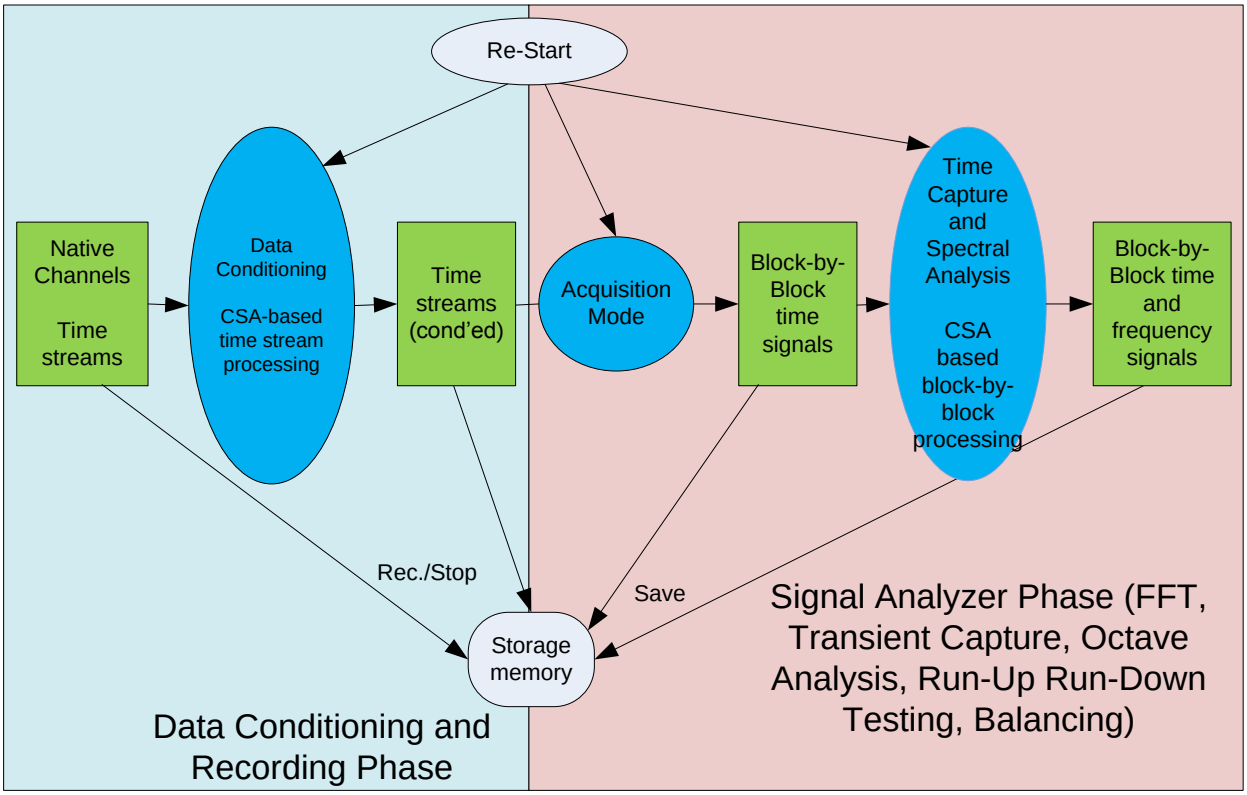


Figure 65. Data Process Flow Diagram.

The system has two dedicated buttons that control the data acquisition.

Rec./Stop button only applies to the continuous time streams in the data conditioning phase while the ***Save*** button only applies to the captured time buffer and spectral signals in the signal analyzer phase. Recording and Save cannot be performed at the same time. In the other words, when the time streams is being recorded, the spectral analysis cannot be saved. To save a spectral analysis signal the time recording must first be stopped.

Re-Start soft button re-initializes the data conditioning, acquisition mode control and spectral analysis. It resets the timer of time streams, re-arm the trigger and reset the average number of spectral analysis.

Block Size governs the size of transient capture or FFT processing in the signal analyzer phase. Block Size has no influence on the length of the time streams in the data conditioning phase.

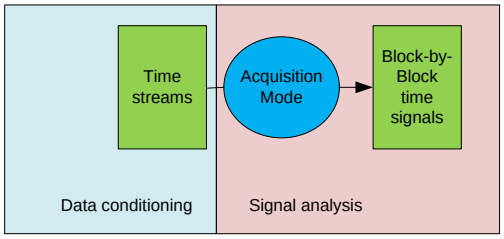
Both time streams and block-by-block signals can be displayed with continuous update (Run mode) or frozen on the screen (Hold mode). In the signal display window the F6 software button is assigned to the ***RUN/Hold*** function. *Hold* means the display and spectral analysis are frozen on the screen. **Hold** does not stop the data conditioning and recording process. If data is being recorded and the Hold button is pressed, the data will continue to be recorded until the Rec/Stop button is pressed again.

The actual Data Conditioning and Signal Analysis function processing are defined by a special technology, CSA, as described in the following section.

Acquisition Mode

This section describes Acquisition Mode which acts as a trigger to capture block by block data from continuous time streams.

The instrument separates the data processing into three stages: data conditioning, acquisition mode and signal analysis. Acquisition Mode controls how the continuous time stream data is captured for block-by-block processing. Acquisition Mode control is applied after data conditioning and before the signal analysis stage. If a CSA does not include a block capture function then Acquisition Mode will not be used.



■ Figure 66. Data processing is separated into three stages.

Note: in the description below, sometimes when we say "capture a block of data", it really means that multiple blocks of data are captured from their own time streams. These blocks are all accurately time-synchronized.

Acquisition Mode

Acquisition Mode defines how the device responds when a trigger event is detected and includes the following options.

Free Run displays block data acquired from the time stream as fast as possible or at the overlap rate by the user. Free Run is commonly used to analyze the random or irregular signals.

Continuous after Trigger waits until a trigger event is detected. After the first trigger event, averaging is reset and the system runs in Free Run mode.

Single Shot with Trigger waits until a trigger event is detected. After the trigger event, the spectral analysis, if there is any, will reset its average back to 1, and waiting for the next trigger. This mode is the best if you want to observe the time signal block by block at a certain trigger event.

Single Shot without Trigger waits until you press the Run button, then acquires one block of data and returns to the wait condition. This mode is the best if you simply want to observe a time signal block by block at an arbitrary time.

Auto-Arm Trigger waits until a trigger event is detected, then a block is acquired and the system returns to the wait condition. If another trigger event is then detected the new block of data will be acquired. This processes will continue indefinitely with no user interaction. Averaging is reset after each trigger event. This mode is the best for repetitive data capture and spectral analysis if you have confidence in the signal quality. Caution should be used because a desired captured block of data can be replaced by a new undesired block of data if an addition trigger event occurs. Use Manual-Arm Trigger to ensure that the last block is not automatically replaced by a new triggered signal.

Manual-Arm Trigger waits until a trigger event is detected, then a block is acquired and the system changes to a hold condition. After the data capture, you will be prompted with an Accept/Reject dialog box. If you accept the new data capture then the block will be included into the average and the system will return to the wait mode. If you reject the new data capture, the new block will be discarded and the system will return to the wait for trigger mode. This mode is the best for applications such as impact hammer testing where you may not have confidence in the signal quality of some of the data blocks.

Trigger Source

Trigger Source defines what signal is used to determine a trigger event. Any time stream that is set as trigger source candidate in the CSA can be selected as trigger source on the CoCo-80. If a signal is not identified as a trigger source candidate in the CSA file then the signal will not appear on the list. This feature is designed to simplify the user interface and optimize the CoCo-80 computation resources.

The candidates of Acquisition Mode selection and Trigger Source selection will be defined by the CSA editor. The CSA editor will assign some the data streams after the data conditioning as candidates of trigger sources. For example, in a CSA there are 8 channels, if you only select ch1 and ch2 time streams as candidates of trigger source and then this CSA will only show ch1 and ch2 on the trigger source selection menu.

You may also define time streams other than native channels as trigger source candidate. For example, if in the CSA an RMS measurement is derived from ch1, this RMS time stream can be used as a trigger source.

Trigger Condition

Trigger Condition defines when a trigger is detected based on the signal level and the slope. The four choices are:

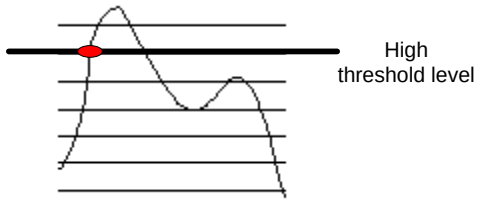
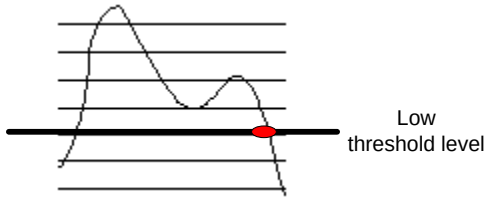
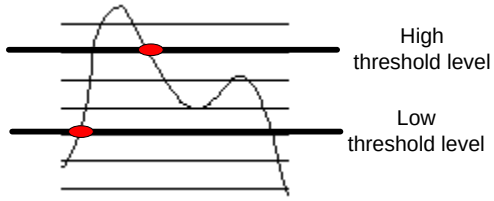
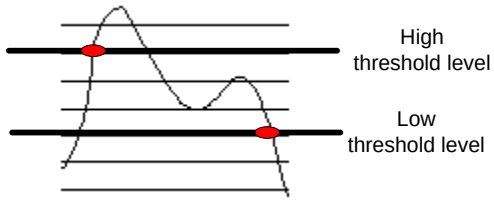
1. ***Trigger Source > High Level (rising edge)***
2. ***Trigger Source < Low Level (falling edge)***
3. ***Low Level < Trigger Source < High Level (level trigger)***
4. ***(Trigger Source > High Level) OR (Trigger Source < Low Level) (edge trigger)***

There are two types of trigger detection, one is called edge detection; the second level detection. In the trigger conditions above, 1, 2 and 4 are edge detection and 3 the level detection. Edge

detection compares at least two sample points against the threshold level. Level detection only detects one sample point.

When ***Free Run*** is selected, trigger source and level are not needed.

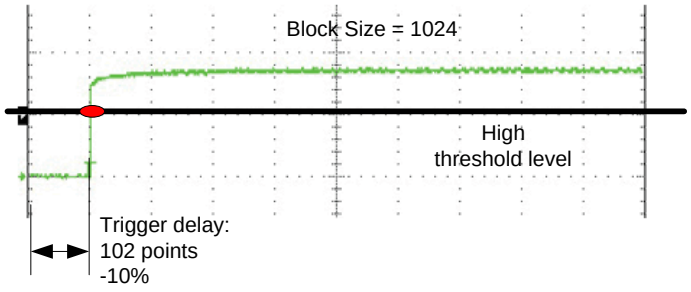
The table below visually explains when the trigger event will happen in these four conditions. The red mark shows the instant in time that the trigger event is detected:

Trigger Condition	Visual Explanation
Trigger Source > High Level (rising edge)	
Trigger Source < Low Level (falling edge)	
Low Level < Trigger Source < High Level (level trigger)	
(Trigger Source > High Level) OR (Trigger Source < Low Level) (edge trigger)	

Trigger Delay

Trigger delay allows a captured signal to include some data before or after the trigger event. This is done by defining some number of points, or the percentage of the total Block Size, that the capture occurs after the trigger event. For example, if the Block Size is set to 1024 and the trigger delay is 10%, the data capture will happen 102 points after the trigger event.

A negative trigger delay is more common for transient data capture. Negative trigger delay means that the data capture will include data points before the trigger event. For example, a -10% trigger delay means that the data capture will include 102 data points before the trigger event with Block Size 1024. Some instruments call a negative trigger delay a ***Pre-Trigger***. The following picture shows the concept of a negative trigger delay:



■ Figure 67. Pre-Trigger (negative delay) example.

Overlap

When overlap is enabled, then the data is averaged from data frames that are overlapping. This reduces the averaging time. Overlap is only used when the Acquisition Mode is set to ***Free Run*** or ***Continuous after Trigger.*** Otherwise it is not used. Continuous capture without further trigger can also use overlapping.

No Overlap – Overlap is not applied.
Automatic – System determines the best overlap rate
25% Overlap – Frames are overlapped by 25%.
50% Overlap – Frames are overlapped by 50%.
75**% Overlap** – Frames are overlapped by 75%.

Acquisition Mode Setup

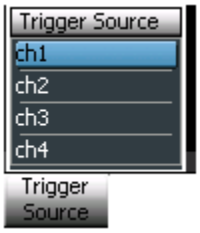
This section explains how to set up the acquisition mode and the trigger related parameters. First select the Acquisition Mode under the Param. Setting then the acquisition mode screen will be shown.

The soft buttons are assigned with different functions:

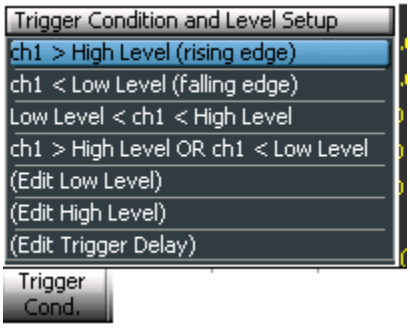
Press F1 to select one of the acquisition modes:

When the Acquisition Mode is not **Free Run**, the Trigger Source, Trigger Condition must be defined.

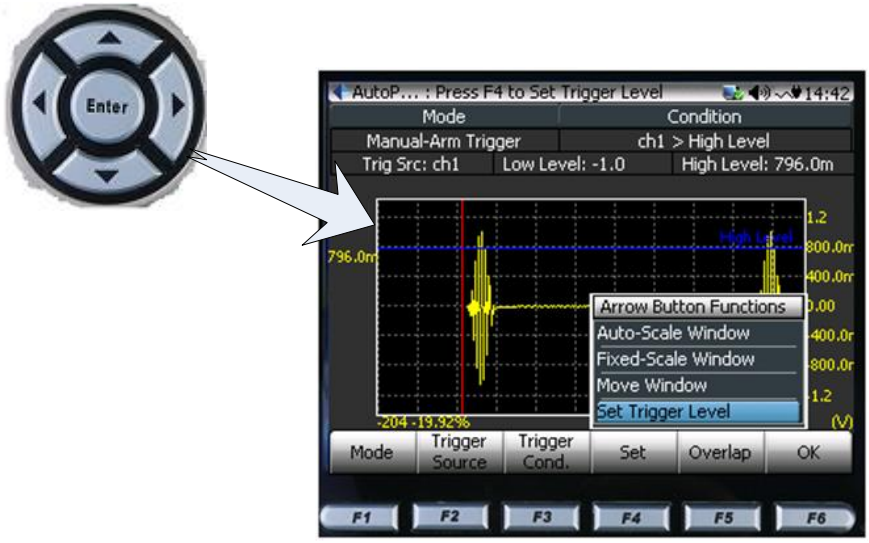
Press F2, Trigger Source, to select one of the time streams as the trigger source. These time streams are set as Trigger Source Candidates by the CSA Editor when this CSA project is created on the host PC.



Press F3, *Trigger Cond.*, to select one of the trigger conditions. You can also key in the trigger level(s) using Editing Level entry.


Trigger Condition and Level Setup
ch1 > High Level (rising edge)
ch1 < Low Level (falling edge)
Low Level < ch1 < High Level
ch1 > High Level OR ch1 < Low Level
(Edit Low Level)
(Edit High Level)
(Edit Trigger Delay)
Trigger Cond.

The arrow buttons can also be used to set the trigger level and delay settings.



Use the arrow buttons to change the trigger level and delay while the data stream from the trigger source is displayed.

Press F4 to activate one of four functions for the navigation arrow buttons

1. Auto Scaling Window
2. Fixed Scale Window: Arrow buttons used for expanding or reducing the scales
3. Moving window: Arrow buttons used to shift the positions of the window
4. Arrow buttons are used to set the high threshold level, low threshold level, and trigger delay

The method 3 is a more convenient way to set the trigger threshold level instead of using the editing tool under F3. The editing tool allows you to set the trigger level to a precise value.

Press F5 to set the overlap rate. This factor will only have effect when the acquisition mode is set as **Free Run** or **Continuous after Trigger**.

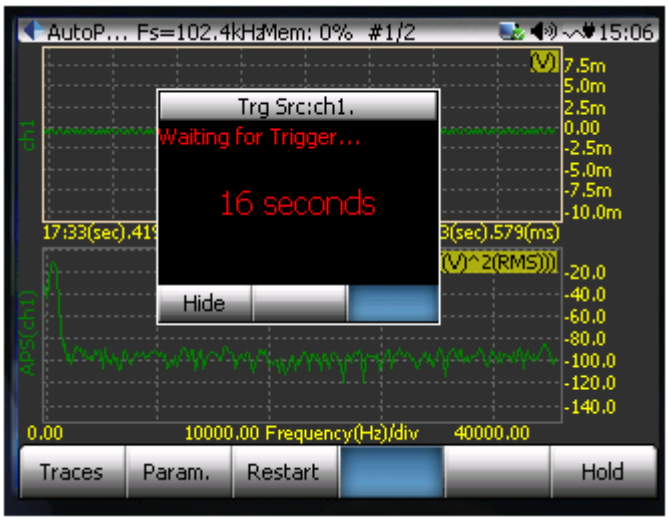
After all trigger parameters are set, press F6 (OK) button then the system will exit to the main measurement display window.

Using a Trigger during Measurement

This section explains the trigger operation while making measurements. Manual-Arm Triggering is the most common mode and will be described first and in the most detail. The other types will be explained briefly afterwards.

Manual Arm Trigger

When the Acquisition mode is setup then a small popup window is displayed as shown in Figure 68 indicating that the system is waiting for a trigger event. No signals are displayed until a trigger event is detected.

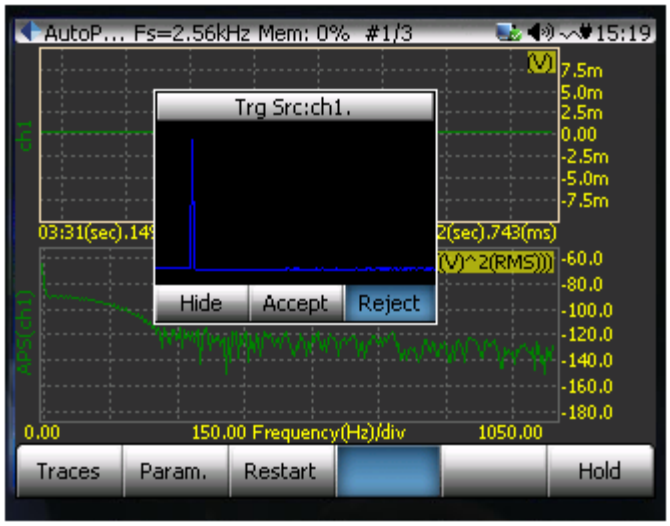


- Figure 68. Waiting for trigger message.

You can change from the waiting for trigger mode to Hold mode by pressing the F6 (Hold) button. The window will close and the system will change to Hold mode.

Press Restart (F3) or Run (F6) to reopen the window and return to the waiting for trigger mode.

When a trigger event occurs due to the Trigger Source signal meeting the trigger condition, the popup window will show a block of capture of data from the trigger source signal.



■ Figure 69. Trigger window with Accept or Reject options.

The display will depend on the type of signals in the pane.

1. If a time stream is displayed then the display will update continuously. You will not notice the difference before or after trigger event for the time stream.

2. If a block signal is displayed, the block signal(s) in the background window will be updated with the new content.

3. If a block signal in the frequency domain is displayed, it will not be updated because you have not "accept" the time signal yet.

Now you may do one of two things: **Accept** or **Reject**.

If you press the **Accept** button, the acquired block signals will be passed to the signal analysis stage, usually windowing, FFT and spectral analysis. Then you can continue to the **Next** frame of capture.

After you press the **Next** key, the system will go back to waiting in trigger mode.

If you press **Reject** then the captured time signals will be discarded and will not be sent to signal analysis stage. After the **Reject** action, the system goes back to waiting in trigger mode.

The number showed on the top status bar, #N, indicates the number of the frames of the time captures that have been *accepted* and averaged into the spectra.

After you press the **Hide** key, the small from window will disappear. Press **Enter** to show this window again.

During trigger operation you can switch the main display window to any trace. This can be helpful to view the time stream selected as the trigger source to tune the level and slope settings.

Save Data to flash Memory or SD memory card

Introduction

Ranging from different applications, several ways are devised to save the signals that are being measured. The media of storage can be either internal flash memory or SD memory card.

Save Long Time Waveform Signal: the time streams can be saved either automatically by a preset schedule or manually.
Save Block Signals: The transient capture time signals, frequency signals or other block signals can be saved automatically or manually.
Save Points: The current value of the time streams, or RMS of a spectrum, or multiple statistics of signals, can be saved automatically or manually in to one file over long period of time. This is particularly useful in the monitoring applications.

The data can be saved either manually or automatically.

Save Long Time Waveform Signals

The Rec./Stop Button is used to control the streaming of time stream data to memory. After a CSA project is selected, pressing the Rec./Stop button will start the display and also start recording the time stream to memory. The red flashing Rec icon at the top of the screen indicates that the data is recording.

To stop the recording press the Rec./Stop button again. The red flashing Rec icon will not be displayed indicating that the recording has stopped.

Before a time stream can be recorded it must be defined in the Parameter Settings/Time Steam Recording Setup. If no time streams are defined in this setting when the Rec./Stop button in pressed then a message will indicate that no signal are selected.

The Rec./Stop button can also be pressed after the Run button is pressed. The Run button starts the display of live signals but does not start recording. After a recording is stopped the display will continue to display live signals until the Hold button is pressed.

A special data compression algorithm is developed in order to save the storage space. It only applies to time stream recording.

For uncompressed data, use following formula to calculate the total time duration that you can record:

Total Installed Flash Memory in Bytes = (Total Channel Enabled) * (Recording Time in Seconds) * (Sampling Rate) * 8 Bytes * 1.2

Or

Recording Time in Seconds = Total Installed Memory in Bytes/((Total Channel Enabled) * (Sampling Rate) * 8 Bytes * 1.2)

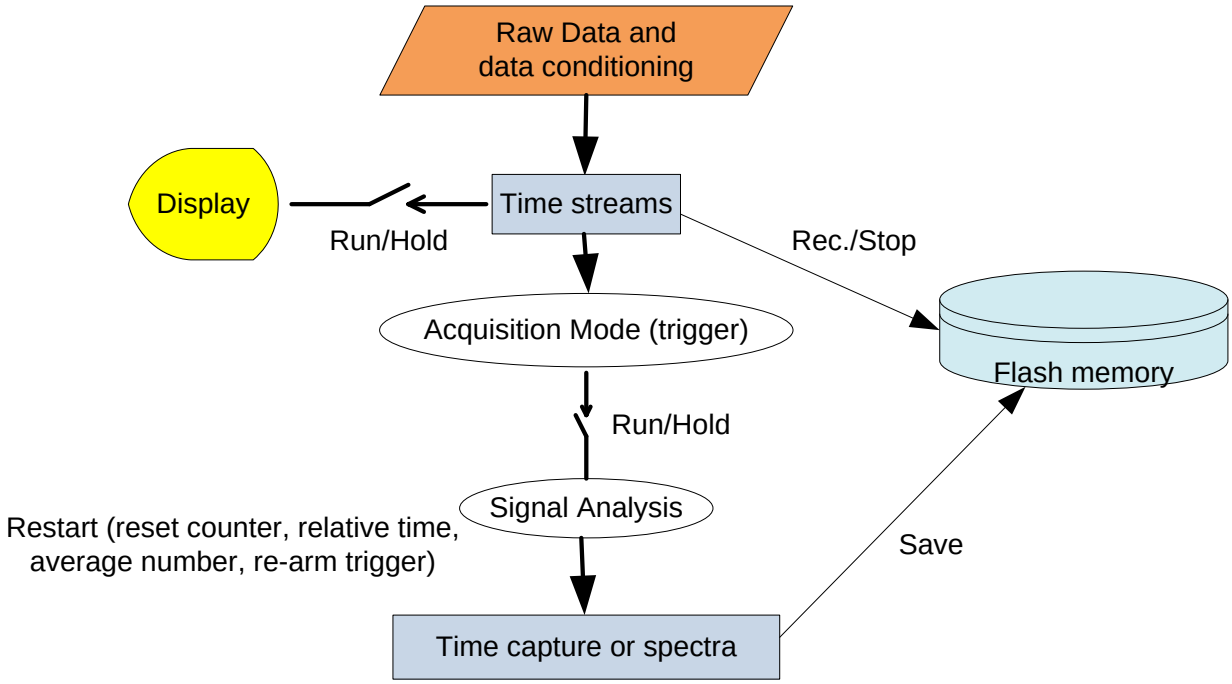
For example if you enabled 6 channels, the sampling rate is 100 Hz with 4GB memory installed:

Recording Time in Seconds = 4GB/(6*100*8*1.2) = 4*1024*1024*1024/(6*100*8*1.2) = 745654 sec (= 207 hours)

When data compression is used, the storage space will be doubled. The spectrum dynamic range of compressed data will be reduced to about 100dB.

If the storage space and downloading time is not an issue for your application, then data compression should not be used.

The figure below illustrates the difference between the concepts of **Display - Run/Hold**, **Time Stream - Record/Stop** and **Signal** - **Save**. The Display mode is independent of the Record or Save functions. When you change the Display mode between Run and Hold it has no effect on the Save or Record functions. That means that time streams can continue to be recorded when the display is in Hold mode.



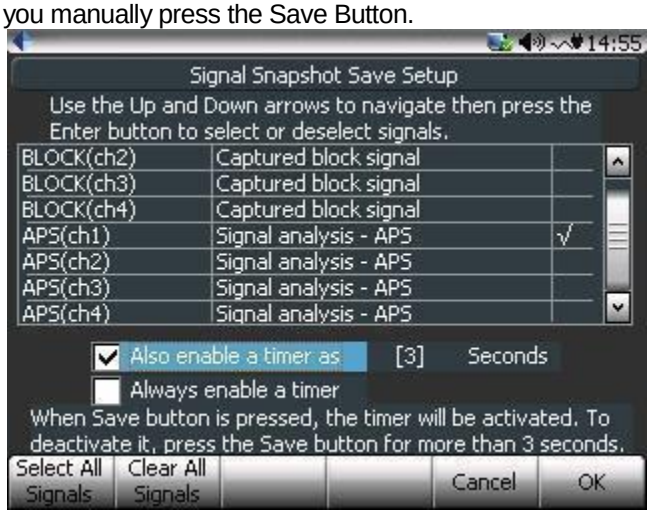
■ Figure 70. Illustration of the difference between Display Run/Hold, Time Stream Record/Stop and Signal Save.

Save Block Signals

Data can be saved by defining which signals to save and under what conditions. Select Signal Snapshot Save Setup under the Param. Button.

■ Figure 71. Signal snapshot save setup.

Choose which signals should be saved by using the Up and Down Arrows and the Enter Button to add a check next to the desired signals. These signals will be saved during a measurement when you manually press the Save Button.


14:55
Signal Snapshot Save Setup
Use the Up and Down arrows to navigate then press the Enter button to select or deselect signals.
BLOCK(ch2) Captured block signal
BLOCK(ch3) Captured block signal
BLOCK(ch4) Captured block signal
APS(ch1) Signal analysis - APS √
APS(ch2) Signal analysis - APS
APS(ch3) Signal analysis - APS
APS(ch4) Signal analysis - APS
Also enable a timer as [3] Seconds
Always enable a timer
When Save button is pressed, the timer will be activated. To deactivate it, press the Save button for more than 3 seconds.
Select All Signals
Clear All Signals
Cancel
OK

■ Figure 72. Signal snapshot save setup.

In addition, these signals can be automatically saved by placing a check next to Also enable a timer and specifying the number of seconds between automatic saves. The signals can be saved with no delay between blocks by selecting Save Signals Continuously. This option can be used to view all data blocks on a waterfall plot.

Save Points

Save Points function saves a data point per signal at one time. This function is particularly useful in the very long period monitoring applications. For example people can save and monitor the vibration or acoustic level over a few months by looking at the data points saved every hour.

All data points in one test will be saved into one data file. The user can easily open, view and analyze the data files using EDM PC software.

To set up the Save Points, first go to Param.->Signal Save Predefined List screen, then press F4 the Save Point Setup button, a tab display will be shown. The user can select one of following items for any time signal to save:

Current Value, Max, Min, Peak, Average, RMS.

Or the user can select one of following items for spectrum signals to save:

Peak, RMS, Frequency of Peak

Or the user can select one of following items for Sound Level Meter measurement to save:

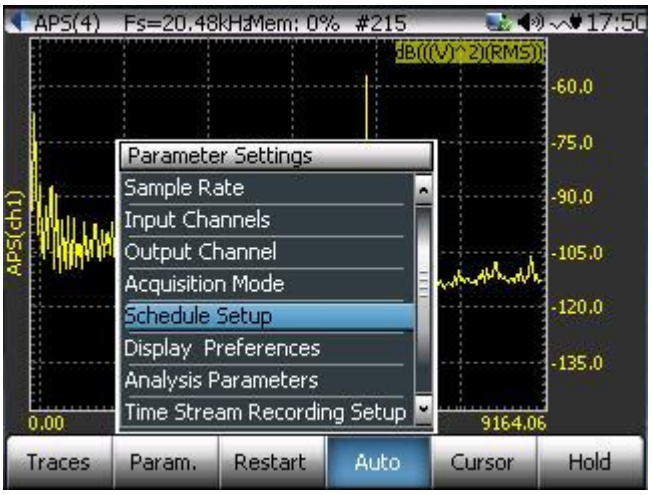
Leq, Lmax

Using Schedule to Save Data

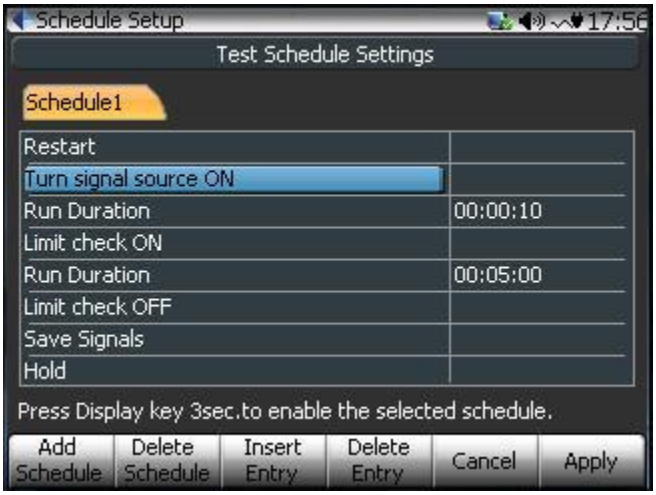
An automated schedule can be developed for recording the time streams, saving the block signals or data points.

- Restart
- Hold
- Run Duration regardless Trigger
- Run Duration after Trigger
- Waiting for one time
- LOOP
- END LOOP
- Limit check ON
- Limit check OFF
- Start Recording
- Stop Recording
- Save Signals
- Turn signal source ON
- Turn signal source OFF
- Activate Timer to Save Signals
- Deactivate Timer to Stop Saving Signals
- Set all input mode

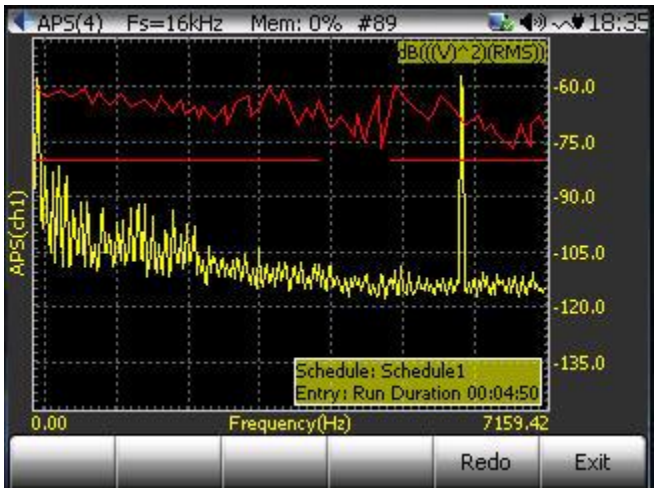
To make a schedule, first go to the Schedule Setup screen:



Insert appropriate entries into the schedule:



To activate the schedule, press the Display button for more than 3 seconds, then release the button.



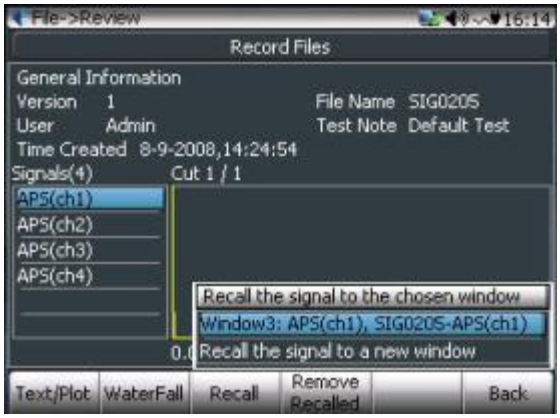
To deactivate the schedule, press F6 the Exit button in the signal display screen.

Recall Signals

Signals that are the result of a current measurement are named "live" signals. Occasionally it is helpful to compare live signals with previously saved signals and stored on the CoCo device. This can be done with the recall feature. Recalled signals can be overlaid with live signals for comparison or displayed in a separate window. Signals can also be un-recalled which removed them from all displays but does not affect the data saved on the CoCo.

To recall the signals that you just saved, simply press the Recall hard button.

To recall a signal that you previously saved, press the File Button, then press the F1 Files Button then press the F5 Review Button, Next use the up and down arrow buttons to highlight a signal to be recalled and press the. F3 Recall Button. Next highlight a signal from the Record Files list and then press the F3 Recall Button.

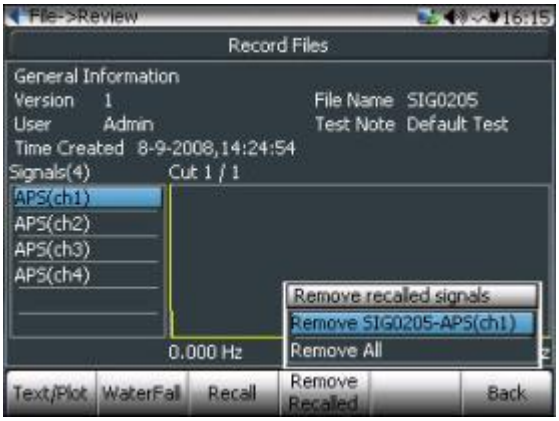


- Figure 73. File review screen for recalling signals.

The CoCo will show a menu listing all available windows that this signal can be recalled into. The last item is always "Recall the signal to a new window". This item will create a new display window

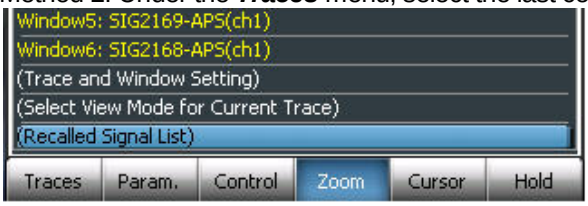
in the current active project and display the recalled signal into this window. Other selections will allow the recalled signal to be overlaid with the others.

After a signal is recalled, it can then be un-recalled. This removes the signal from the all displays however the original data file remains stored on the CoCo. To un-recall a signal, take one of the following two actions.

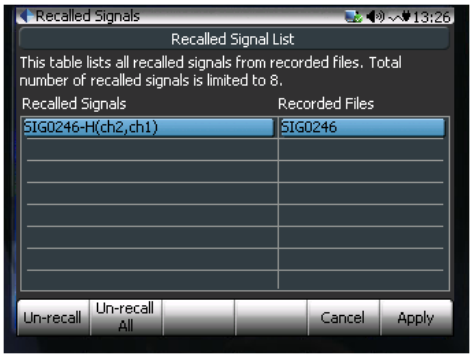


■ Figure 74. Recall signal pop up menu.

Method 1: In the above file menu, press F4 to see all signals that can be un-recalled. You can either unrecall one signal or un-recall all of them.
Method 2: Under the ***Traces*** menu, select the last command *(Recalled Signal List)*:

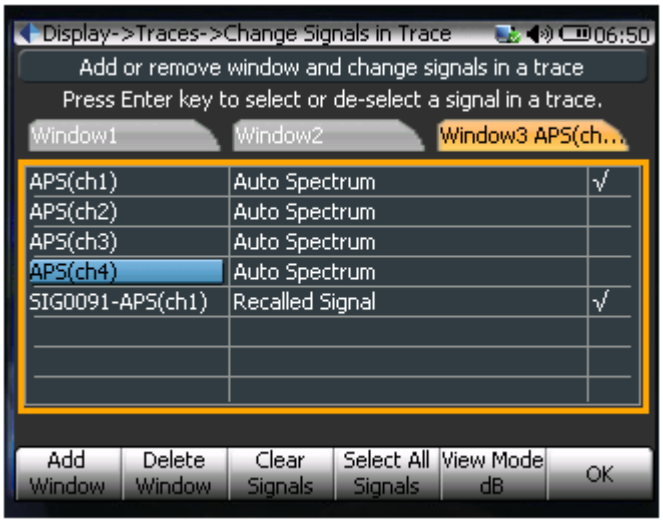


■ Figure 75. Recall signals from the trace menu.



■ Figure 76. Un-recall signal.

The recalled signals will have a signal name with a prefix of its file name. The recalled signals can be displayed in the same way as live signals.

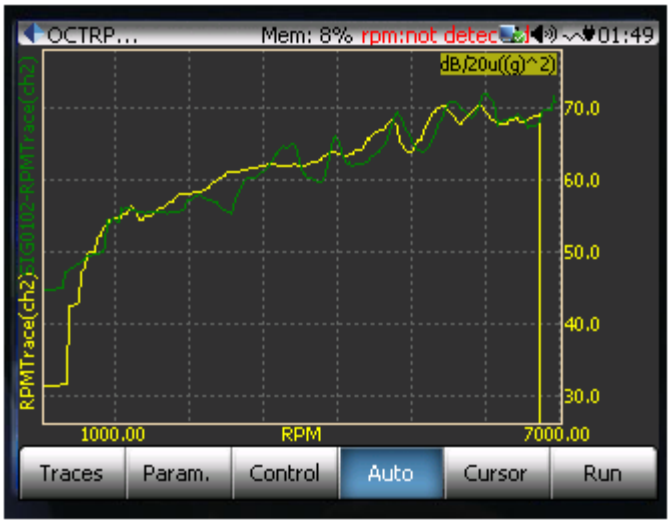


- Figure 77. Recalled signals appear with file name prefix.

The picture below shows a recalled signal in green color overlaid with a live signal in yellow.

- Figure 78. Live signal overlaid with recalled signal.

The picture below shows the saved RPM trace signal in octave analysis that is overlaid with the current live measurement.



- Figure 79. RPM live signal overlaid with recalled signal.

4. BASICS OF DYNAMIC SIGNAL ANALYSIS

DSA, often referred to Dynamic Signal Analysis or Dynamic Signal Analyzer depending on the context, is an application area of digital signal processing technology. Compared to general data acquisition and time domain analysis, DSA instruments and math tools focus more on the dynamic aspect of the signals such as frequency response, dynamic range, total harmonic distortion, phase match, amplitude flatness etc.. In recent years, time domain data acquisition devices and DSA instruments have gradually converged together. More and more time domain instruments, such as oscilloscopes, can do frequency analysis while more and more dynamic signal analyzers can do long time data recording.

DSA uses various different technology of digital signal processing. Among them, the most fundamental and popular technology is based on the so called the Fast Fourier Transform (FFT). The FFT transforms the time domain signals into the frequency domain. To perform FFT-based measurements, however, you need to understand the fundamental issues and computations involved. This Chapter describes some of the basic signal analysis computations, discusses antialiasing and acquisition front end for FFT-based signal analysis, explains how to use windowing functions correctly, explains some spectrum computations, and shows you how to use FFT-based functions for some typical measurements.

General Theory of Spectral Analysis

In this Chapter we will use standard notation for different signals. Each type of signal will be represented by one specific letter. For example, "G" stands for a one-side power spectrum, while "H" stands for a transfer function.

The following table defines the symbols used in this Chapter:

Cyx	Coherence function between input signal x and output signal y
Gxx	Auto-spectral function (one-sided) of signal x
Gyx	Cross-spectral function (one-sided) between input signal x and output signal y
Hyx	Transfer function (Frequency Response) between input signal x and output signal y
k	Index of a discrete sample
Rxx	Auto-correlation function of signal x
Ryx	Cross-correlation function between input signal x and output signal y
Sx	Linear spectral function of signal x
Sxx	Instantaneous auto-spectral function (one-sided) of signal x
Syx	Instantaneous cross-spectral function (one-sided) between input signal x and output signal y
t	Time variable
x(t)	Time history record
X(f)	Fourier Transform of time history record

Fourier Transform

Digital signal processing technology includes FFT based frequency analysis, digital filters and many other topics. This chapter introduces the FFT based frequency analysis methods that are widely used in all dynamic signal analyzers. CoCo has fully utilized the FFT frequency analysis methods and various real time digital filters to analyze the measurement signals.

The Fourier Transform is a transform used to convert quantities from the time domain to the frequency domain and vice versa, usually derived from the Fourier integral of a periodic function when the period grows without limit, often expressed as a Fourier transform pair. In the classical sense, a Fourier transform takes the form of

$$X(f) = \int_{-\infty}^{\infty} x(t) e^{-j\,2\pi f t}\, dt$$

where

x(t)	continuous time waveform
f	frequency variable
j	complex number
X(f)	Fourier transform of *x(t)*

Mathematically the Fourier Transform is defined for all frequencies from negative to positive infinity. However, the spectrum is usually symmetric and it is common to only consider the single-sided spectrum which is the spectrum from zero to positive infinity." For discrete sampled signals, this can be expressed as

$$X(k) = \sum_{n=0}^{N-1} x(k) e^{-j\,2\pi k n\,/N}$$

where

x(k)	samples of time waveform
n	running sample index
N	total number of samples or "frame size"
k	finite analysis frequency, corresponding to "FFT bin centers"
X(k)	discrete Fourier transform of *x(k)*

In most DSA products, a Radix-2 DIF FFT algorithm is used, which requires that the total number of samples must be a power of 2 (total number of samples in FFT = 2^m , where m is an integer).

Data Windowing

The Fourier Transform assumes that the time signal is periodic and infinite in duration. When only a portion of a record is analyzed the record must be truncated by a data window to preserve the frequency characteristics. A window can be expressed in either the time domain or in the frequency domain, although the former is more common. To reduce the edge effects, which cause leakage, a window is often given a shape or weighting function. For example, a window can be defined as

w(t) = g(t)	*-T/2 < t < T/2*
= 0	elsewhere

where *g(t)* is the window weighting function and *T* is the window duration.

The data analyzed, *x(t)* are then given by

$$x(t) = w(t)\, x(t)'$$

where *x(t)'* is the original data and *x(t)* is the data used for spectral analysis.

A window in the time domain is represented by a multiplication and hence, is a convolution in the frequency domain. A convolution can be thought of as a smoothing function. This smoothing can be represented by an effective filter shape of the window; i.e., energy at a frequency in the original data will appear at other frequencies as given by the filter shape. Since time domain windows can be represented as a filter in the frequency domain, the time domain windowing can be accomplished directly in the frequency domain.

In most DSA products, rectangular, Hann, Flattop and several other data windows are used;

Rectangular Window

$$w(k) = 1 \qquad 0 \le k \le N-1$$

Hann Window

$$w(k) = 0.5 * (1 - \cos(2\pi k /(N-1)) \qquad 0 \le k \le N-1$$

Because creating data window attenuates a portion of the original data, a certain amount of correction has to be made in order to get an un-biased estimation of the spectra. In linear spectral analysis, an *Amplitude Correction* is applied; in power spectral measurements, an *Energy Correction* is applied. See the sections below for details.

Linear Spectrum

A linear spectrum is the Fourier transform of windowed time domain data. The linear spectrum is useful for analyzing periodic signals. You can extract the harmonic amplitude by reading the amplitude values at those harmonic frequencies.

An averaging technique is often used in the time domain when synchronized triggering is applied. Or equivalently, the averaging can be applied to the complex FFT spectra.

Because the averaging is taking place in the linear spectrum domain, or equivalently, in the time domain, based on the principles of linear transform, averaging make no sense unless a synchronized trigger is used.

Most DSA products use the following steps to compute a linear spectrum:

Step 1
First a window is applied:

$$x(t) = w(t)\, x(t)'$$

where *x(t)'* is the original data and *x(t)* is the data used for the Fourier transform.

Step 2

The FFT is applied to *x(t)* to compute *X(k)*, as described above.

Step 3
Averaging is applied to *X(k)*. Here Averaging can be either an Exponential Average or Stable Average. Result is *Sx'*.

Sx' = Average (X(k))

Step 4
To get a single-sided spectrum, double the value for symmetry about DC.
An Amplitude Correction factor is applied to *Sx'* so that the final result has an un-biased reading at the harmonic frequencies.

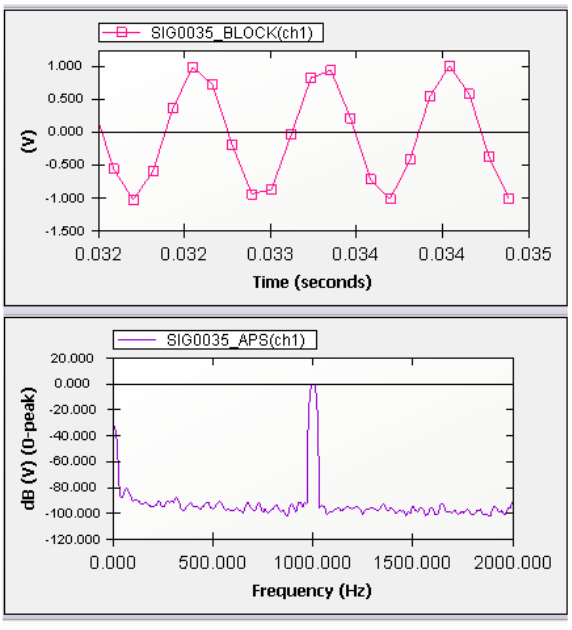
$$Sx = 2 \bullet Sx' / AmpCorr$$

where AmpCorr is the amplitude correction factor, defined as:

$$AmpCorr = \sum_{k=0}^{N-1} w(k)$$

where *w(k)* is the window weighting function.

This correction will make the peak or RMS reading of a sine wave at specific frequency correct regardless of which data window is applied. For example, if a 1.0 volt amplitude 1kHz sine wave sampled at 6.4kHz is analyzed with a Linear Spectrum with Hann window, you will get following the spectral shape:

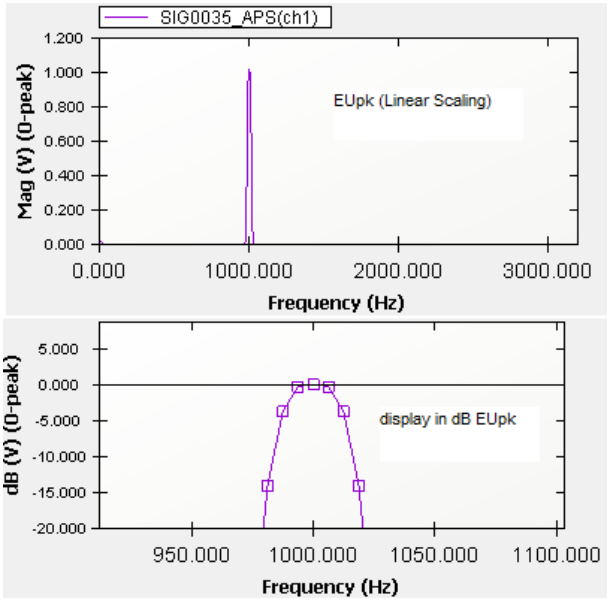


■ Figure 80. Sine wave with Hanning window applied to the spectrum.

The top picture is the digitized time waveform. The sine-wave is not smooth because of the low sampling rate relative to the frequency of the signal. However the well known Nyquist principle indicates that the frequency estimate from the FFT will be accurate as long as the sampling rate is

more than twice of the signal frequency. The frequency spectrum of the period signal will show the accurate frequency and level. Note for a more accurate sample of the time waveform a higher sampling rate is required.

Figure 81 illustrates a windowing function applied to a pure sine tone.



■ Figure 81. Hanning windowing function applied to a pure sine tone.

The top picture is displayed in EUpk, i.e., the peak of the spectrum is scaled to the actual 0 peak level, which is 1.0 in this case. The bottom picture shows the same signal with the dB scale applied. Since we use 0dB as reference, the 1.0 Vpk is now scaled to 0.0 dB. With the dB display, we can see frequency points around the peak causing by the Hanning window.

In many DSA products, amplitude correction is automatically applied when you select different Spectrum Types. For details about Spectrum Types, see the section entitled Spectrum Types in this Chapter.

The linear spectrum is saved internally in the complex data format with real and imaginary parts. Therefore, you should be able to view the real and imaginary parts, or amplitude and phase of the spectrum.

Power Spectrum

Spectral analysis is popular in characterizing the operation of mechanical and electrical systems. A type of spectral analysis, the power spectrum (and power spectral density (PSD)), is especially popular because a "power" measurement in the frequency domain is one that engineers readily accept and apply in their solutions to problems. Single channel measurements (auto-power spectra) and two channel measurements (cross-power spectra) both play important roles.

In power spectrum measurements, window ***amplitude correction*** is used to get un-biased final spectrum amplitude reading at specific frequency. In PSD or energy spectral density (ESD) measurements, window ***energy correction*** is always used to get an un-biased spectral density or energy reading.

To compute the spectra listed above, the instrument will follow these steps:

Step 1
A window is applied:

$x(k) = w(k)\, x(k)'$

where $x(k)'$ is the original data and $x(k)$ is the data used for a Fourier transform.

Step 2
The FFT is applied to $x(t)$ to compute Sx

$$Sx = \sum_{n=0}^{N-1} x(k) e^{-j\,2\pi kn\,/N}$$

Next the so called periodogram method is used to compute the spectra with area correction. Using Sx.

Step 3

Calculate the Power Spectrum $Sxx = Sx\, Sx^{*} / (AmpCorr)^2$

Or calculate the Power Spectral Density $= Sx\, Sx^{*}\, T / EnergyCorr$

Or calculate the Energy Spectral Density $= Sx\, Sx^{*}\, T^2 / EnergyCorr$

where T is the time duration of the capture. The symbol * is for complex conjugation. *EnergyCorr* is a factor for energy correction, which is defined as:

$$EnergyCorr = \frac{1}{N}\sum_{k=0}^{N-1} w(k)^2$$

N is the total number of the samples and $w(k)$ is window function.

For any power spectral measurement of the three types listed above, the EU is automatically chosen as EU_{rms} because only EU_{rms} has a physical meaning related to signal power.

After the power spectra are calculated, the averaging operation will be applied. More details will be discussed in the next sections for averaging operation.

Spectrum Types

Several Spectrum Types are given for both Linear Spectrum and Power Spectrum measurements in CoCo and EDM. The concept of spectrum type is explained below in detail.

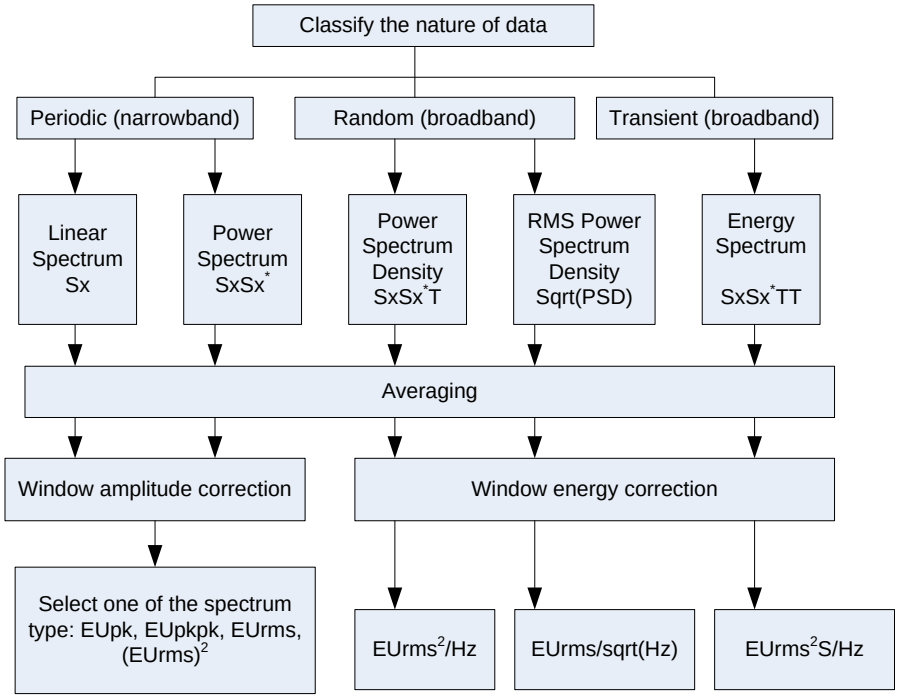
First let's consider the signals with periodic nature. These can be the signals measured from a rotating machine, bearing, gearing, or anything that repeats. In this case we would be interested in amplitude changes at fundamental frequencies, harmonics or sub-harmonics. In this case, you can choose a spectrum type of EU_{pk}, EU_{pkpk} or EU_{rms}.

A second scenario might consist of a signal with a random nature that is not necessarily periodic. It does not have obvious periodicity therefore the frequency analysis could not determine the "amplitude" at certain frequencies. However, it is possible to measure the r.m.s. level, or power level, or power density level over certain frequency bands for such random signals. In this case, you must select one of the spectrum types of EU_{rms}^2/Hz, or EU_{rms}/sqrt(Hz), which is called power spectral density, or root-mean squared density.

A third scenario might consist of a transient signal. It is neither periodic, nor stably random. In this case, must select a spectrum type as EU^2S/Hz, which is called energy spectrum.

In many applications, the nature of the data cannot be easily classified. Care must be taken to interpret the data when different spectrum types are used. For example, in the environmental vibration simulation, a typical test uses multiple sine tones on top of random profile, which is called Sine-on-Random. In this type application, you have to observe the random portion of the data in the spectrum with EU_{rms}^2/Hz and the sine portion of the data with EU_{pk}.

Figure 82 shows a general flow-chart to choose one of the measurement techniques and spectrum types for linear or auto spectrum:

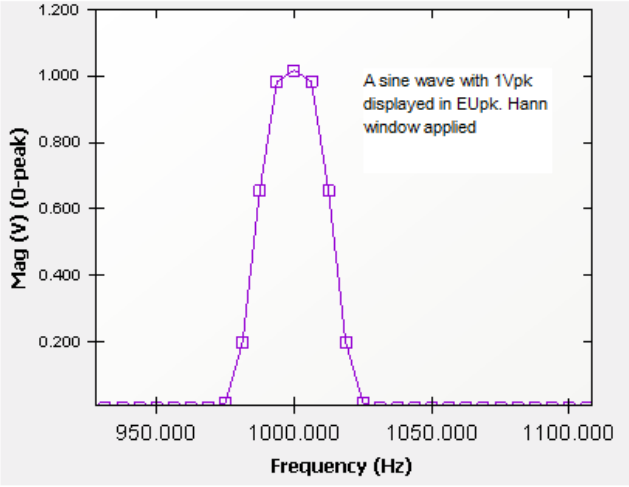


■ Figure 82. Flow chart to determine measurement technique for various signal types.

The following figures illustrate the results of different measurement techniques on a 1 volt pure sine tone. The figures include RMS, Peak or Peak-Peak value for the amplitude, or power value corresponding to its amplitude. Notice these readings can only be applied to a periodic signal. If you applied these measurement techniques to a signal with random nature, the spectrum would not be a meaningful representation of the signal.

EU_{pk} or EU_{pkpk}

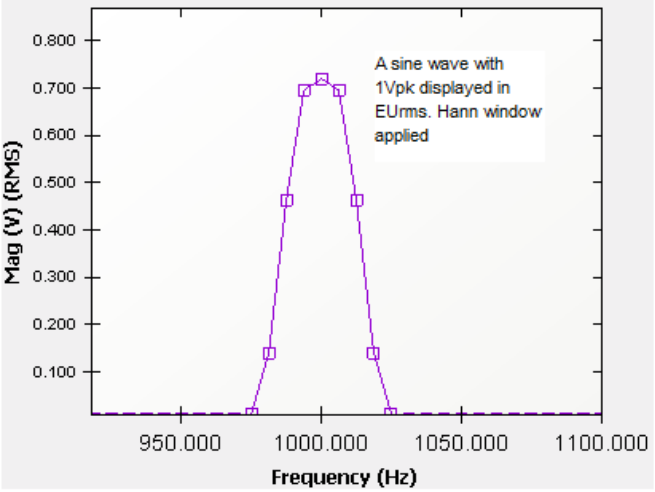
The EU_{pk} and EU_{pkpk} displays the peak value or peak-peak value of a periodic frequency component at a discrete frequency. These two spectrum types are suitable for narrowband signals.



- Figure 83. A sine wave is measured with EUpk spectrum unit. The sine waveform has a 1V amplitude.

EU_{rms}

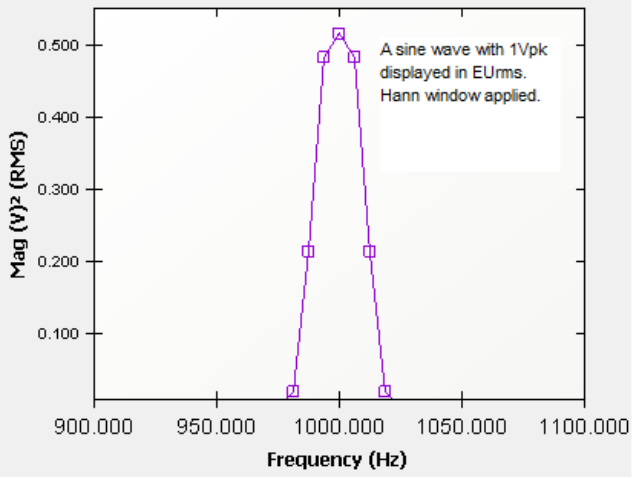
The EU_{rms} displays the RMS value of a periodic frequency component at a discrete frequency. This spectrum type is suitable for narrowband signals.



- Figure 84. A sine wave is measured with EUrms spectrum unit. The peak reading is 0.707V. The sine waveform has a 1V amplitude.

$(EU_{rms})^2$ Power spectrum

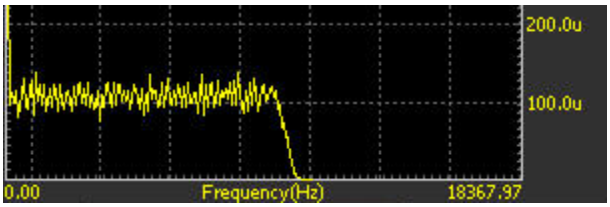
The $(EU_{rms})^2$ displays the power reading of a periodic frequency component at a discrete frequency. This spectrum type is suitable for narrowband signals.



■ Figure 85. A sine wave is measured with (EUrms)2 spectrum unit. The peak reading is 0.5V^2. The sine waveform has a 1V amplitude.

EU^2/Hz, Power Spectrum Density

The EU^2/Hz is the spectrum unit used in power spectrum density (PSD) calculations. The unit is in engineering units squared divided by the equivalent filter bandwidth. This provides power normalized to a 1Hz bandwidth. This is useful for wideband, continuous signals. EU^2/Hz really should be written as $(EU_{rms})^2$/Hz. But probably due to the limitation of space, people put it as EU^2/Hz.



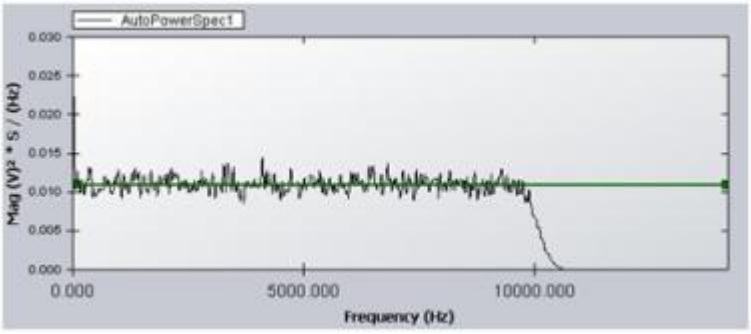
■ Figure 86. White noise with 1 volt RMS amplitude and volts^2/Hz PDS units.

Figure 86 shows a white noise signal with $1V_{rms}$ amplitude or $1V^2$ in power level. The bandwidth of the signal is approximately 10000 Hz and the V^2/Hz reading of the signal is around 0.0001 V^2/Hz. The 1 V RMS can be calculated as follows:

$$1\ V_{rms} = \text{sqrt}\ (10000Hz * 0.0001\ V^2/Hz)$$

EU^{2}S/Hz, Energy Spectrum Density

The EU^{2}S/Hz displays the signal in engineering units squared divided by the equivalent filter bandwidth, multiplied by the time duration of signal. This spectrum type provides energy normalized to a 1Hz bandwidth, or energy spectral density (ESD). It is useful for any signals when the purpose is to measure the total energy in the data frame. Figure 87 shows a random signal with a 1 volt RMS level in the ESD format.



■ Figure 87. Random signal with 1 volt RMS amplitude and Energy Spectrum Density format.

The ESD is calculated as follows:

Values for ESD = values of PSD * Time Factor

were the Time Factor = (Block size)/Δf and Δf is the sampling rate / block size.

Notice that in **EU^2/Hz**, or **EU^2S/Hz,** EU really means the RMS unit of the EU, i.e., EU_{rms}.

It should also be noted that since a window is applied in time domain, which corresponds a convolution in the linear spectrum, we cannot have both a valid amplitude and correct energy correction at the same time. Use Figure 82 to select appropriate spectrum types.

In a Linear Spectrum measurement, a signal is saved in its complex data format which includes both real and imaginary data. Then is averaging operation applied to the linear spectrum. In a Power Spectrum measurement, the averaging operation is applied to the squared spectrum, which has only real part. Because of different averaging techniques, the final results of Linear Spectrum and Power Spectrum will be different even though the same spectrum type is used.

Spectrum Types selection only applies to Power Spectrum and Linear Spectrum signals. Spectrum Types do not apply to transfer functions, phase functions or coherence functions.

Cross Spectrum

Cross spectrum or cross power spectrum density is a frequency spectrum quantity computed using two signals, usually the excitation and response of a dynamic system. Cross spectrum is not commonly used by its own. Most often it is used to compute the frequency response function (FRF), transmissibility or cross correlation function.

To compute the cross-power spectral density *Gyx* between channel x and channel y:

Step 1, compute the Fourier transform of input signal x(k) and response signal y(k):

$$Sx = \sum_{n=0}^{N-1} x(k)\, w(k) e^{-j\,2\pi kn\,/N}$$

$$Sy = \sum_{n=0}^{N-1} y(k)\, w(k) e^{-j\,2\pi kn\,/N}$$

Step 2, compute the instantaneous cross power spectral density

Syx = Sx Sy T*

Step 2, average the *M* frames of *Sxx* to get averaged PSD *Gxx*

Gyx' = Average (Syx)

Step 3, Compute the energy correction and double the value for the single-sided spectra

Gyx = 2 Gyx' / EnergyCorr

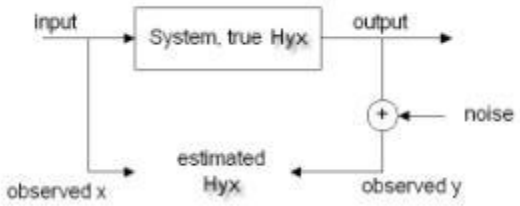
Frequency Response and Coherence Function

The cross power spectrum method is often used for estimating the frequency response function (FRF) between channel x and channel y. The equation is:

$$H_{yx} = G_{yx} / G_{xx}$$

where *Gyx* is the averaged cross-spectrum between the input channel x and output channel y. *Gxx* is the averaged auto-spectrum of the input. Either power spectrum, power spectral density or energy spectral density can be used to compute the FRF because of the linear relationship between input and output.

Using the cross-power spectrum method instead of simply dividing the linear spectra between input and output to calculate the FRF will reduce the effect of the noise at the output measurement end, as shown below.



■ Figure 88. Frequency response function computation.

The frequency response function has a complex data format. You can view it in real and imaginary or magnitude and phase display format.

The coherence function is defined as:

$$C_{yx}^{\ 2} = \frac{|G_{yx}|^2}{G_{xx}G_{yy}}$$

where *Gyx* is the averaged cross-spectrum between the input channel x and output channel y. *Gxx* and *Gyy* are the averaged auto-spectrum of the input and output. Either power spectrum, power spectral density or energy spectral density can be used here because of the linear relationship between input and output so that any multiplier factors will be cancelled out.

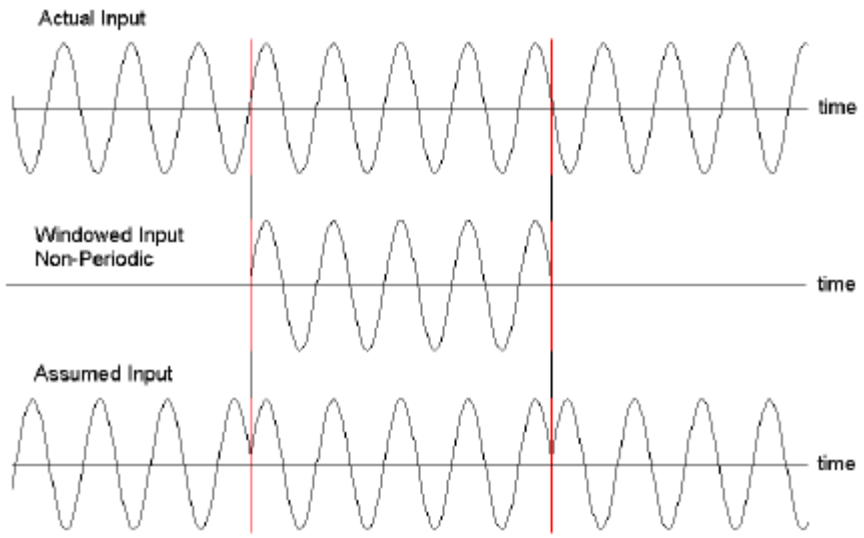
Coherence is a statistical measure of the how much of the output is caused by the input. The maximum coherence is 1.0 when the output is perfectly correlated with the input and zero when there is no correlation between input and output. Coherence is calculated by an average of multiple frames. When it is computed for only one frame, then the coherence function has a meaningless result of 1.0 due to the estimation error of the coherence function.

The coherence function is a non-dimensional real function in the frequency domain. You can only view it in the real format.

Data Window Selection

Leakage Effect

Windowing of a simple signal, like a sine wave may cause its Fourier transform to have non-zero values (commonly called leakage) at frequencies other than the frequency of this sine. This leakage effect tends to be worst (highest) near sine frequency and least at frequencies farthest from sine frequency. The effect of leakage can easily be depicted in the time domain when a signal is truncated. As shown in the picture, after data windowing, truncation distorted the time signal significantly, hence causing a distortion in its frequency domain.



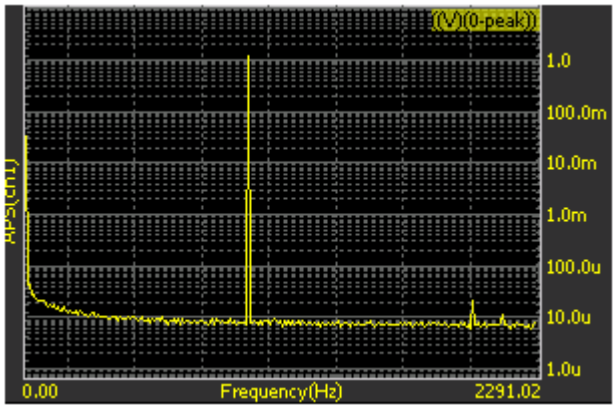
■ Figure 89. Illustration of a non-periodic signal resulting from sampling.

If there are two sinusoids, with different frequencies, leakage can interfere with the ability to distinguish them spectrally. If their frequencies are dissimilar, then the leakage interferes when one sinusoid is much smaller in amplitude than the other. That is, its spectral component can be hidden or masked by the leakage from the larger component. But when the frequencies are near each other, the leakage can be sufficient to interfere even when the sinusoids are equal strength; that is, they become undetectable.

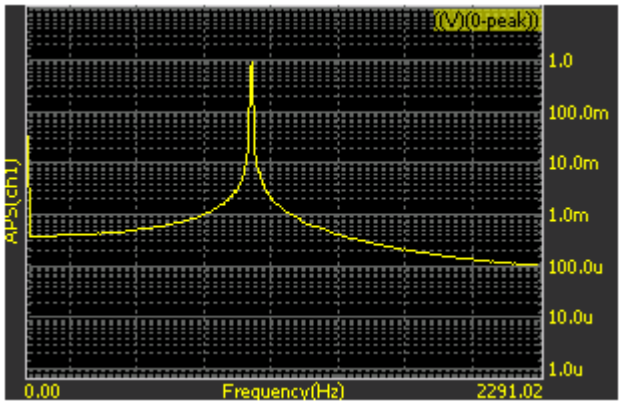
There are two possible scenarios that leakage does not occur. The first is that when the whole time capture is long enough to cover the complete duration of the signals. This can occur with short transient signals. For example in a hammer test, if the time capture is long enough it may extend to the point where the signal decays to zero. In this case, data window is not needed.

The second case is when a periodic signal is sampled at such a sampling rate that is perfectly synchronized with the signal period, so that with a block of capture, an integer number of cycles of the signal are always acquired. For example, if a sine wave has a frequency of 1000Hz and the sampling rate is set to 8000Hz. Each sine cycle would have 8 integer points. If 1024 data points are acquired then 128 complete cycles of the signal are captured. In this case, with no window applied you still can get a leakage-free spectrum.

Figure 90 shows a sine signal at 1000 Hz with no leakage resulting in a sharp spike. Figure 91 shows the spectrum of a 1010 Hz signal with significant leakage resulting in a wide peak. The spectrum has significant energy outside the narrow 1010 Hz frequency. It is said that the energy leaks out into the surrounding frequencies.

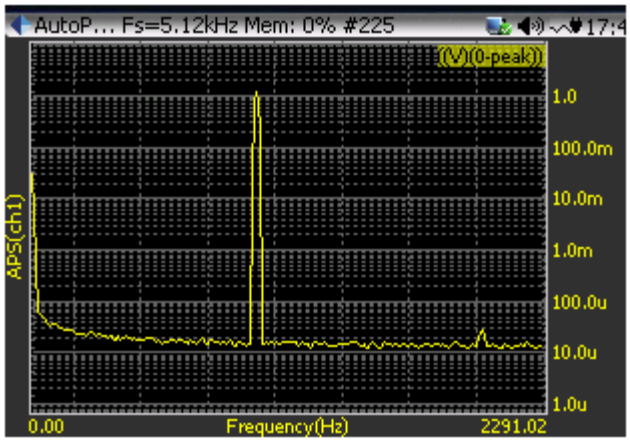


- Figure 90. Sine spectrum with no leakage.



- Figure 91. Sine spectrum with significant leakage.

Several windowing functions have been developed to reduce the leakage effect. The picture below shows a Flattop window applied to the same sine signal with frequency 1010Hz:



■ Figure 92. Sine spectrum with Flattop windowing function.

When Flattop window is used, the leakage effect is reduced. Both the sine peak and noise floor can be seen now. However, such data windowing operation also makes the spectrum peak "fatter" and less accurate. In the rest of the sections we will discuss how to choose different data windows.

Data Window Formula

In this section, we will describe the math formula that we used for each data window.

Uniform window (rectangular)

$$w(k) = 1.0$$

Uniform is the same as no window function.

Hamming window

$$w(k) = 0.53836 - 0.46164 \cos(\frac{2\pi k}{N-1})$$

Hann window

$$w(k) = 0.5 - 0.5 \cos(\frac{2\pi k}{N-1})$$

The Hann and Hamming windows are in the family known as "raised cosine" windows, are respectively named after Julius von Hann and Richard Hamming. The term "Hanning window" is sometimes used to refer to the Hann window, but is ambiguous as it is easily confused with Hamming window.

Blackman window

$$w(k) = 0.84 - 0.5\cos\frac{2\pi k}{N-1} + 0.08\cos\frac{4\pi k}{N-1} \qquad for\ k = 0 \sim N-1$$

Flattop window

$$w(k) = 1 - 1.93\cos\frac{2\pi k}{N-1} + 1.29\cos\frac{4\pi k}{N-1} - 0.388\cos\frac{6\pi k}{N-1} + 0.032\cos\frac{8\pi k}{N-1} \qquad for\ k = 0 \sim N-1$$

Kaiser Bessel window

$$w(k) = 1.0 - 1.24\cos\frac{2\pi k}{N-1} + 0.244\cos\frac{4\pi k}{N-1} + 0.00305\cos\frac{6\pi k}{N-1} \qquad for\ k = 0 \sim N-1$$

Exponential Window

The shape of the exponential window is that of a decaying exponential. The following equation defines the exponential window.

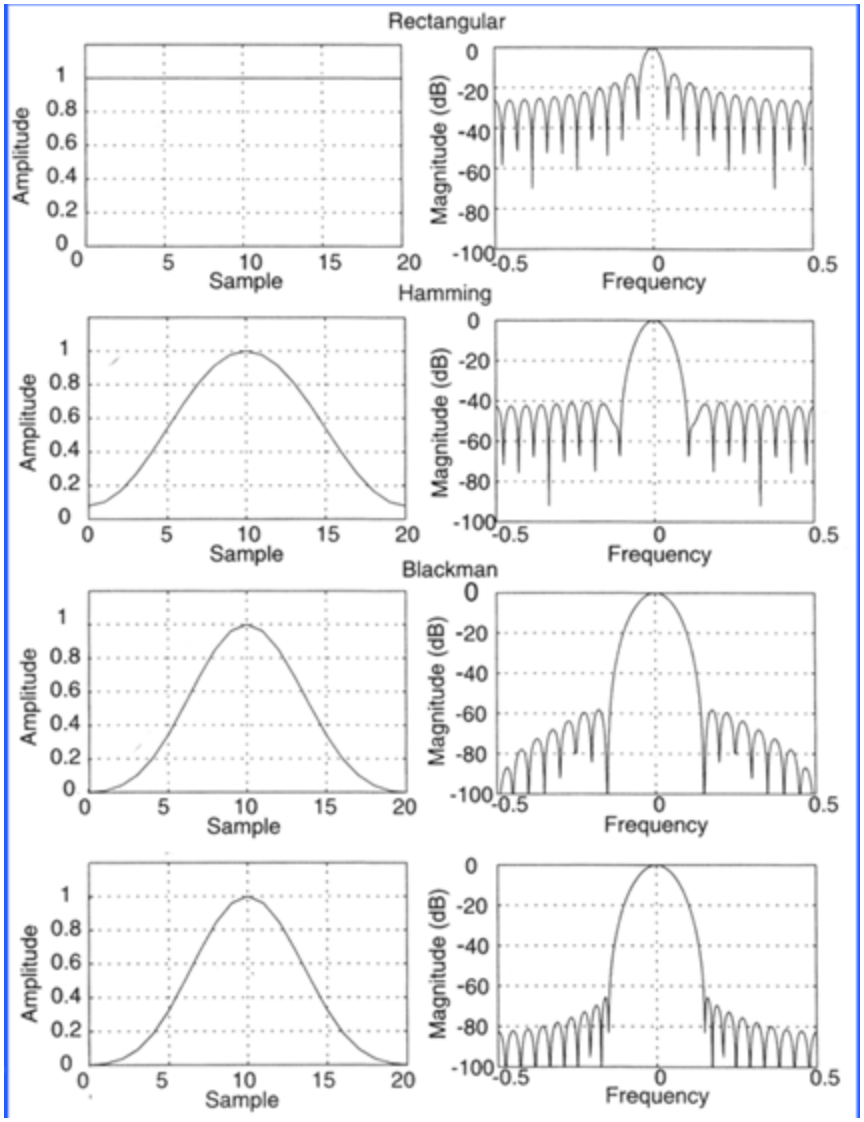
$$w(k) = e^{\left(\frac{k \ln(final)}{N-1}\right)}$$

$$for\ k = 0 \sim N-1$$

where N is the length of the window, w(k)is the window value, and ***final*** is the final value of the whole sequence. The initial value of the window is one and gradually decays toward zero.

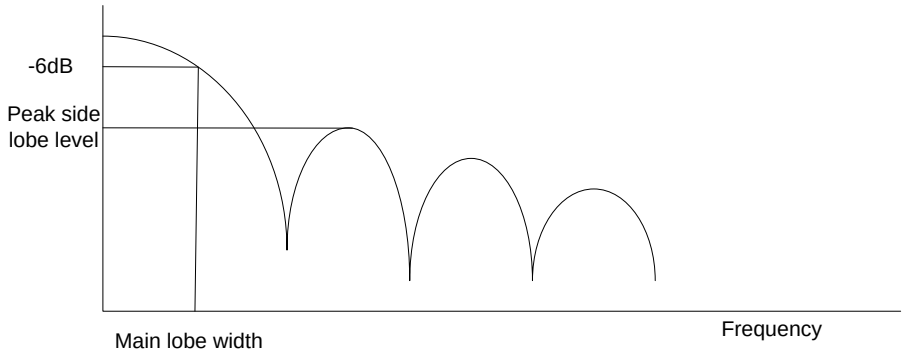
How to Choose the Right Data Window

In this section we will discuss how to choose the data window. Figure 93 shows the spectral shape of four typical windows corresponding to their time waveform.



■ Figure 93. Spectral shape of common windowing functions.

It can be seen that the spectral shape of the data window is always symmetric. The spectral shape can be described as a main lobe and several side lobes.



■ Figure 94. Window frequency response showing main lobe and side lobes.

The following table lists the characteristics of several data windows.

Frequency Characteristics of Data Windows

Window	–3 dB Main Lobe Width (bins)	–6 dB Main Lobe Width (bins)	Maximum Side Lobe Level (dB)
Uniform (none)	0.9	1.2	–13
Hanning	1.4	2.0	–32
Hamming	1.3	1.8	–43
Blackman	1.6	2.3	–58
Flattop	2.9	3.6	–44

Main Lobe

The center of the main lobe of a window occurs at each frequency component of the time-domain signal. By convention, to characterize the shape of the main lobe, the widths of the main lobe at –3 dB and –6 dB below the main lobe peak describe the width of the main lobe. The unit of measure for the main lobe width is FFT bins or frequency lines.

The width of the main lobe of the window spectrum limits the frequency resolution of the windowed signal. Therefore, the ability to distinguish two closely spaced frequency components increases as the main lobe of the smoothing window narrows. As the main lobe narrows and spectral resolution improves, the window energy spreads into its side lobes, increasing spectral leakage and decreasing amplitude accuracy. A trade-off occurs between amplitude accuracy and spectral resolution.

Side Lobes

Side lobes occur on each side of the main lobe and approach zero at multiples of f_s/N from the main lobe. The side lobe characteristics of the smoothing window directly affect the extent to which adjacent frequency components leak into adjacent frequency bins. The side lobe response of a strong sinusoidal signal can overpower the main lobe response of a nearby weak sinusoidal signal. Maximum side lobe level and side lobe roll-off rate characterize the side lobes of a smoothing window. The maximum side lobe level is the largest side lobe level in decibels relative to the main lobe peak gain.

Guidelines of Choosing Data Windows

If a measurement can be made so that no leakage effect will occur, then do not apply any window (in the software, select Uniform.). As discussed before, this only occurs when the time capture is long enough to cover the whole transient range, or when the signal is exactly periodic in the time frame.

If the goal of the analysis is to discriminate two or multiple sine waves in the frequency domain, spectral resolution is very critical. For such application, choose a data window with very narrow main slope. Hanning is a good choice.

If the goal of the analysis is to determine the amplitude reading of a periodic signal, i.e., to read EU_{pk}, EU_{pkpk}, EU_{rms} or EU_{rms}^2, the amplitude accuracy of a single frequency component is more important than the exact location of the component in a given frequency bin, choose a window with a wide main lobe. Flattop window is often used.

If you are analyzing transient signals such as impact and response signals, it is better not to use the spectral windows because these windows attenuate important information at the beginning of the sample block. Instead, use the Force and Exponential windows. A Force window is useful in analyzing shock stimuli because it removes stray signals at the end of the signal. The Exponential window is useful for analyzing transient response signals because it damps the end of the signal, ensuring that the signal fully decays by the end of the sample block.

If the nature of the data is has a random nature or unknown, choose Hanning window.

Averaging Techniques

Averaging is widely used in spectral measurements. It improves the measurement and analysis of signals that are purely random or mixed random and periodic. Averaged measurements can yield either higher signal-to-noise ratios or improved statistical accuracy.

Typically, three types of averaging methods are available in DSA products. They are:

Linear Averaging, **Exponential Averaging**, and **Peak-Hold**

Linear Averaging

In linear averaging, each set of data (a record) contributes equally to the average. The value at any point in the linear average in given by the equation:

$$Averaged = \frac{Sum\ of\ Records}{N}$$

N is the total number of the records. The advantage of this averaging method is that it is faster to compute and the result is un-biased. However, this method is suitable only for analyzing short signal records or stationary signals, since the average tends to stabilize. The contribution of new records eventually will cease to change the value of the average.

Usually, a target average number is defined. The algorithm is made so that before the target average number reaches, the process can be stopped and the averaged result can still be used.

When the specified target averaging number is reached, the instrument usually will stop the acquisition and wait for the instruction for another collection of data acquisition.

Moving Linear Averaging

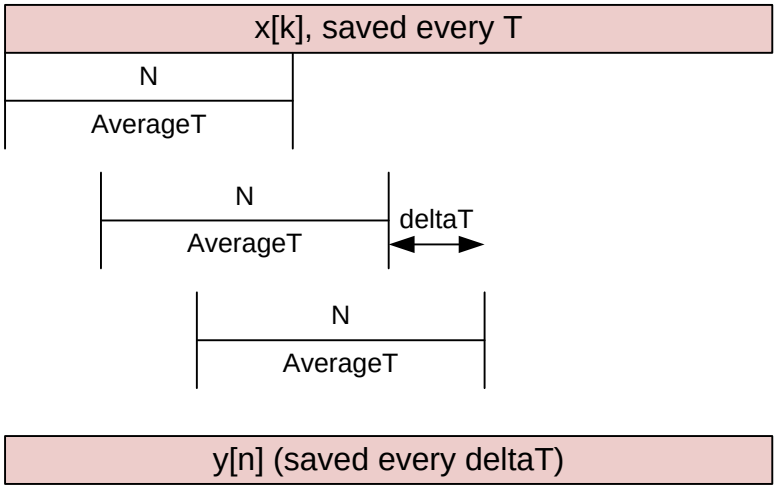
In a regular Linear Average, the data rate of the output of the averaging operator is only 1/N of that of the original signal. Therefore more averages takes longer to compute. Thus averaging will increase the time of the measurement. To reduce the time a Moving Linear Averaging can be used. Moving Linear Averaging uses overlapped input data points to generate more than 1/N results within a period of time. Moving linear average has the advantage that the resulted trace update time can be much shorter than the linear averaging period.

Moving Linear Average is computed by

$$y[n] = \frac{1}{N}\sum_{j=0}^{N-1} x[n-j]$$

Where x[k] is the input data, with sampling rate of T, y[n] is the output data, with Trace Update rate deltaT, AverageT is the period of Linear Average and ,N is the total samples used for Linear Average. N = AverageT/T

The Moving Linear Averaging is illustrated in Figure 95. Assume the averaging period is *AverageT* but the progressive time for each averaging operation is *deltaT*, the output buffer will have a data rage of *deltaT* instead of *AverageT*.



- Figure 95. Illustration of moving linear average.

The Moving Linear Average is useful in many situations. For example, in Sound Level Meter, Leq is defined as a linear averaged value over a long period of time, say 1 second to 24 hours. Assume the AverageT is 1 hour, without moving linear average, in a 24 hours period, you can only get 24 readings. This is not very useful. With moving averaging, you can get the readings in every 1 second, for the linear averaging of the past 1 hour.

Exponential Averaging

In exponential averaging, records do not contribute equally to the average. A new record is weighted more heavily than old ones. The value at any point in the exponential average is given by:

$$y[n] = y[n-1] * (1-\alpha) + x[n] * \alpha$$

where $y[n]$ is the *nth* average and $x[n]$ is the nth new record. α is the weighting coefficient. Usually α is defined as 1/(Number of Averaging). For example in the instrument, if the Number of Averaging is set to 3 and the averaging type is selected as exponential averaging, then $\alpha = 1/3$

The advantage of this averaging method is that it can be used indefinitely. That is, the average will not converge to some value and stay there, as is the case with linear averaging. The average will dynamically respond to the influence of new records and gradually ignore the effects of old records.

Exponential averaging simulates the analog filter smoothing process. It will not reset when a specified averaging number is reached.

The drawback of the exponential averaging is that a large value may embed too much memory into the average result. If there is a transient large value as input, it may take a long time for y[n] to decay. On the contrary, the contribution of small input value of x[n] will have little impact to the averaged output. Therefore, exponential average fits a stable signal better than a signal with large fluctuations.

Peak-Hold

This method, technically speaking, does not involve averaging in the strict sense of the word. Instead, the "average" produced by the peak hold method produces a record that at any point represents the maximum envelope among all the component records. The equation for a peak-hold is

$$y[n] = \mathrm{MAX}_{\mathrm{j}=0}^{\mathrm{N}-1}(x[n-j])$$

Peak-hold is useful for maintaining a record of the highest value attained at each point throughout the sequence of ensembles. Peak-Hold is not a linear math operation therefore it should be used carefully. It is acceptable to use Peak-Hold in auto-power spectrum measurement but you would not get meaningful results for FRF or Coherence measurement using Peak-Hold.

Peak-hold averaging will reset after a specified averaging number is reached.

Time versus Power Spectrum Averaging

Averaging can be applied to either time domain or power spectrum. If you want to reduce the spectral estimation variance, use power spectral averaging. If you want to extract repetitive or periodic small signals from a noisy signal, you can use triggered capture and average them in time domain. Time averaging must be performed with on a triggered event so that the time signal of one average is correlated with other similar measurements. Without time synchronizing mechanism, averaging makes no sense.

Power Spectrum Averaging is also called RMS Averaging. RMS averaging computes the weighted mean of the sum of the squared magnitudes (FFT times its complex conjugate). The weighting is either linear or exponential. RMS averaging reduces fluctuations in the data but does not reduce the actual noise floor. With a sufficient number of averages, a very good approximation of the actual random noise floor can be displayed. Since RMS averaging involves magnitudes only, displaying the real or imaginary part, or phase, of an RMS average has no meaning and the power spectrum average has no phase information.

Table 2 gives a summary of the averaging methods described above.

- Table 2. Summary of Averaging Methods.

Time Averaging	Power Spectrum Averaging
No statistical spectral estimate, for deterministic signals only.	Statistical spectral estimate, for signals with random characteristics.
Signal must have periodic components.	Applicable to both pure random and mixed random/periodic signals.
Improve SNR.	Does not improve SNR.
Requires a synchronized trigger in fixed relation to the signals.	Does not require a synchronized trigger.

In CoCo-80, the user can select ***Linear, Exponential*** and ***Peak Hold*** for power spectral averaging and select ***Time Linear*** or ***Time Exponential*** for time domain averaging.

Spectrum Estimation Error

You may wonder how much confidence we should have when we take the spectral measurement. This is an academic topic that can go very deep. First you must classify your signal types. If you are measuring a deterministic signal, with very few averaging, the spectrum estimation can be very accurate. If the signal has a random nature, with partially random, or significant measurement noise, more averaging must be used.

Assume the time data is captured from a stationary random process and we calculate various spectra using window, FFT and averaging techniques, how much we can trust the measured spectra can be measured by a statistical quantity, *standard deviation*. Here are a few useful equations to compute the standard deviation of the spectra when linear averaging is used:

Functions being estimated	Standard Deviation
Auto-spectrum Gxx	$\frac{1}{\sqrt{n}}$
Cross-spectrum |Gyx|	$\frac{1}{\lvert Cyx \rvert \sqrt{n}}$
Coherence Function Cyx^2	$\frac{(1-Cyx^2)\sqrt{2}}{\lvert Cyx \rvert \sqrt{n}}$
Frequency Response Function Hyx	$\frac{\sqrt{(1-Cyx^2)}}{\lvert Cyx \rvert \sqrt{2n}}$

where *n* is the average number in linear averaging. The transfer function is computed in the cross-power spectrum method as presented earlier.

Assume a signal is random and has an ***expected*** power spectral density at 0.1 V^2/Hz. The goal of a measurement is to average a few power spectra and to estimate such an expected value. If the average number is 1, meaning, with no average, the standard deviation of the error of such a measurement will be 100%. When we average two frames of auto power spectra, the standard deviation of the error will become $\frac{1}{\sqrt{2}} = 70.7\%$ When the average number is increased to 100, the standard deviation of the error of the reading is 10%. This means that the reading is likely in the neighborhood of (0.1±0.01) V^2/Hz

Now if this signal has a deterministic nature, say a sine wave, the spectral estimation error will only be applied to the random portion, i.e., the noisy portion, of this signal.

Coherence Value Affects Accuracy of Spectra Estimate

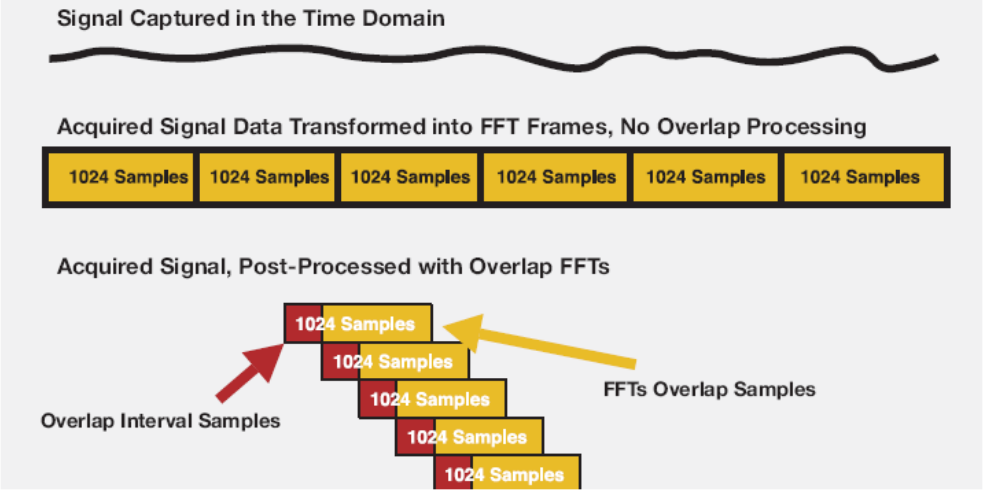
As shown above, the spectral estimation error is related to the coherence value between the input and output. When signal to noise ratio is low, the coherence value will be much less than 1.0 which results in very inaccurate estimation to the FRF and other spectra signals.

To improve the coherence value, the key is to increase the signal intensity of the excitation signal at the frequency range of interest.

One of the unique features of CoCo is that the random signal of its signal source is well-controlled within the analysis frequency band. This design allows the excitation focus its energy between DC and analysis frequency. The FRF estimation with such excitation will be more accurate.

Overlap Processing

To increase the speed of spectral calculation, overlap processing can be used to reduce the measurement time. The diagram below shows how the overlap is realized.



■ Figure 96. Illustration of overlap processing.

As shown in this picture, when a frame of new data is acquired after passing the Acquisition Mode control, only a portion of the new data will be used. Overlap calculation will speed up the calculation with the same target average number. The percentage of overlap is called overlap ratio. 25% overlap means 25% of the old data will be used for each spectral processing. 0% overlap means that no old data will be reused.

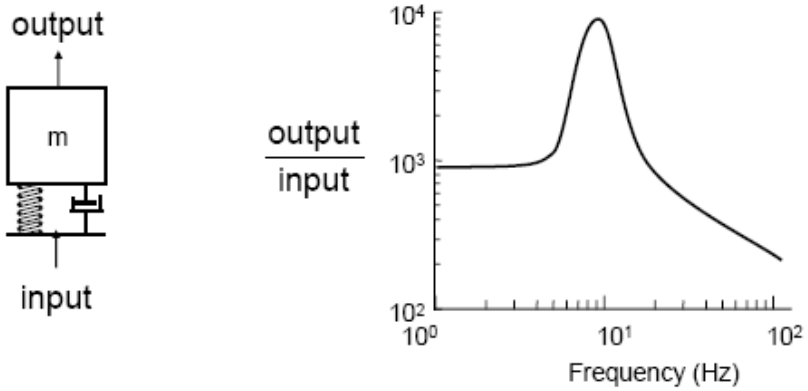
Overlap processing can improve the accuracy of spectral estimation. This is because when a data window is applied, some useful information is attenuated by the data window on two ends of each block. However, it is not true that the higher the overlap ratio the higher the spectral estimation accuracy. For Hanning window, when the overlap ratio is more than 50%, the estimation accuracy of the spectra will not be improved.

Another advantage to apply overlap processing is that it helps to update the display more quickly.

Single Degree of Freedom System

This section briefly discusses the single degree of freedom (SDOF) system as background for the frequency response function and damping estimation methods.

The vibration nature of a mechanical structure can be decomposed into multiple, relatively independent Single-Degree-Of-Freedom systems. Each SDOF system can be modeled as a mass fixed to the ground by a spring and a damper in parallel as shown in Figure 97. The frequency response function (FRF) of this mechanical system is also shown.



■ Figure 97. SDOF system and their frequency response.

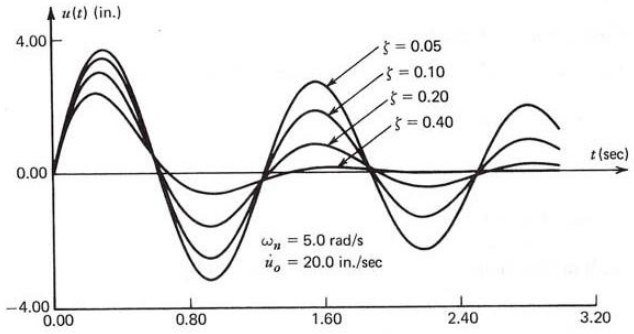
The differential equation of motion for this system is given by

$$m\ddot{x} + c\dot{x} + kx\dot{} = f(t)$$

The natural frequency ω_n and damping ratio ζ can be calculated from the system parameters as

$$\omega_n^2 = \frac{k}{m}, \quad and \quad 2\zeta\omega_n = \frac{c}{m}$$

where m is the mass, k is the spring stiffness and c is the damping coefficient.
The natural frequency, ω_n , is in units of radians per second (rad/s). The typical units displayed on a digital signal analyzer are in Hertz (Hz). The damping ratio, ζ, can also be represented as a percent of critical damping – the damping level at which the system experiences no oscillation. This is the more common understanding of modal damping.. Figure 97 illustrates the response of a SDOF system to a transient excitation showing the effect of different damping ratios.

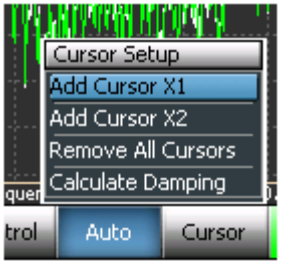


■ Figure 98. Step response of a SDOF system with different damping ratios.

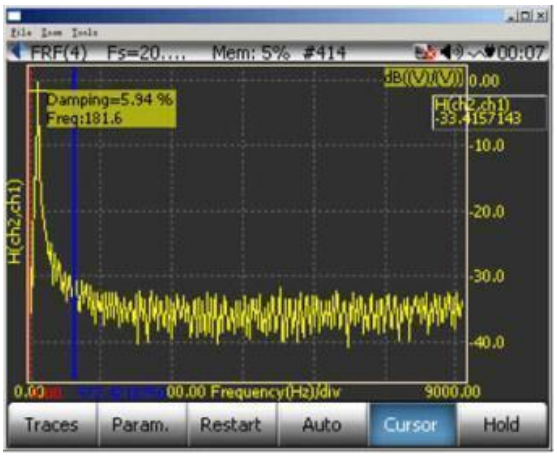
A SDOF system with light damping factor will have longer oscillation in a transient process. This is why the exponential window may be chosen to reduce the leakage effect in its spectral analysis. On the other hand, the exponential window may artificially change the spectral shape so the estimated damping is biased. Since most modern instruments allow can capture very long buffer of data, it is preferred to increase the buffer length instead of applying the exponential window.

Damping factor and the resonant frequency can be calculated by using curve fit method that applies to the FRF signal. Without curve fit, the estimation of damping value can go off significantly especially in a light damping system.

In CoCo or EDM software, the user can use dual cursors to calculate these values, as show in the picture below.



Enable two cursors and cover the peak area, then select ***Calculate Damping*** command.



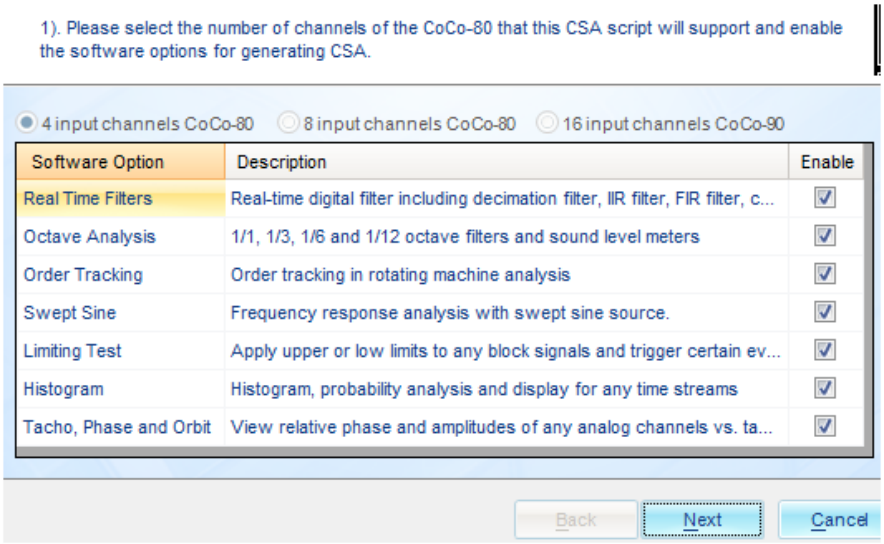
CSA Editor Operation for Spectral Analysis

This section describes the operation of CSA Editor related to FFT based spectral analysis. For general operation of CSA Editor, refer to the CSA User's Manual.

CSA Editor Wizard

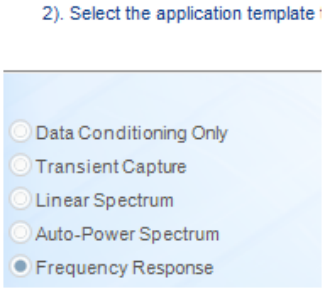
This section summarizes how to create a CSA project for general spectral analysis in the CSA Editor. We strongly recommend that you read the CSA Editor User's Manual to gain more detail information before proceeding with this chapter.

To start, click on the CSA Editor icon in the upper-right corner in EDM and start the CSA Editor. The CSA Editor Wizard dialog box will be displayed.


1). Please select the number of channels of the CoCo-80 that this CSA script will support and enable the software options for generating CSA.
4 input channels CoCo-80
8 input channels CoCo-80
16 input channels CoCo-90
Software Option
Description
Enable
Real Time Filters
Real-time digital filter including decimation filter, IIR filter, FIR filter, c...
Octave Analysis
1/1, 1/3, 1/6 and 1/12 octave filters and sound level meters
Order Tracking
Order tracking in rotating machine analysis
Swept Sine
Frequency response analysis with swept sine source.
Limiting Test
Apply upper or low limits to any block signals and trigger certain ev...
Histogram
Histogram, probability analysis and display for any time streams
Tacho, Phase and Orbit
View relative phase and amplitudes of any analog channels vs. ta...
Back
Next
Cancel

■ Figure 99. CSA Editor Wizard Software Option selection.

Although it does not show up in the software option list, the FFT based spectral analysis is a the heart of the software and is always installed and enabled in the CSA Editor by default. This is true regardless of whether any other software options are enabled in the display.



■ Figure 100. CSA Editor Wizard template selection.

When you are asked to select one of the templates to use, you must selection one of the following: ***Linear Spectrum***, ***Auto Spectrum*** or ***Frequency Response*** as the template in order to calculate the appropriate spectra. The software will open the CSA Application Group associated with the template that you choose.

Linear Spectrum

This application is the best choice for applying data conditioning to native time streams, transforming time streams into block signals and applying data windowing and FFT calculations.

Auto Power Spectrum

This application is the best choice for applying pply data conditioning to native time streams, transforming time streams into block signals and applying data windowing and FFT to calculate auto spectra. FRF/Coh is also calculated in this application.

Frequency Response

This application is best for applying data conditioning to native time streams, transforming time streams into block signals then applying data windowing and FFT to calculate auto spectra, cross spectra, frequency response and coherence functions.

The software determines many factors based on the template selection. Table 3 shows the availability of measurement quantities for the different templates of basic spectral analysis:

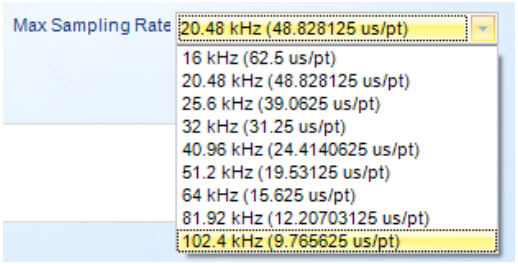
- Table 3. Comparison of measurement quantities for different spectral analysis templates.

CSA Template	Time streams of native channels	Time streams for each data conditioning output	Acquisition Mode, Blocked Time Capture	FFT and Auto-Power Spectra	Cross Spectra	FRF/Coh
Data Conditioning Only	Yes	Yes	No	No	No	No
Transient Capture	Yes	Yes	Yes	No	No	No
Linear Spectrum	Yes	Yes	Yes	Yes	No	No
Auto Power Spectrum	Yes	Yes	Yes	Yes	No	No
Frequency Response	Yes	Yes	Yes	Yes	Yes	Yes

The table illustrates that the *Frequency Response* template contains the most complete measurement quantity set. If you want to measure time streams, block time captures, auto and cross spectra, FRF and coherence all together, select the *Frequency Response* template.

Does this mean that you should always select the *Frequency Response* template because it has all the measurements? The answer is NO. The more measurement quantities that are selected, the more DSP resources that are required. DSP resources refers to both real time computational capability and memory resources. Sometime you have to make a tradeoff between speed, size of the data buffer and the number of measurements taken.

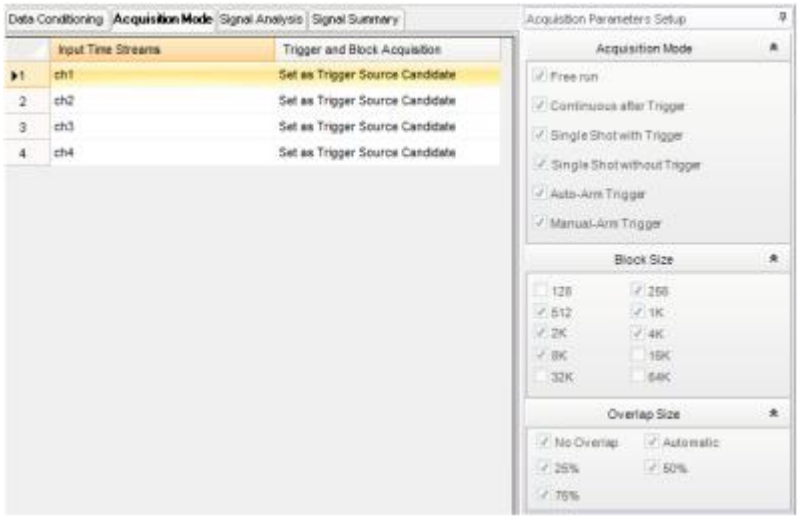
As a rule of thumb, always select the minimum function sets that you need to use. It will save computational resource on DSP.



■ Figure 101. CSA Wizard Template sampling rate selection.

Next, you must choose the ***Maximum Sampling Rate,*** which is a number that controls the highest sampling rate that this CSA project uses. If you allocate too many computational tasks in the following steps, then the sampling rate may have to be reduced. The Editor will give you chances to make the changes later, if necessary. It is best to choose the lowest sampling rate that you know that you will need for your application to conserve DSP resources.

After the CSA Editor Wizard is finished, you may apply various data conditioning modules to the time streams. For details about how to apply the data conditioning modules refer to the User's Manual of CSA Editor. Then go to Acquisition Mode, follow the instructions in the Manuals to set the *trigger source candidate*, *Acquisition Mode*, *Block Size* and *Overlap Size*.



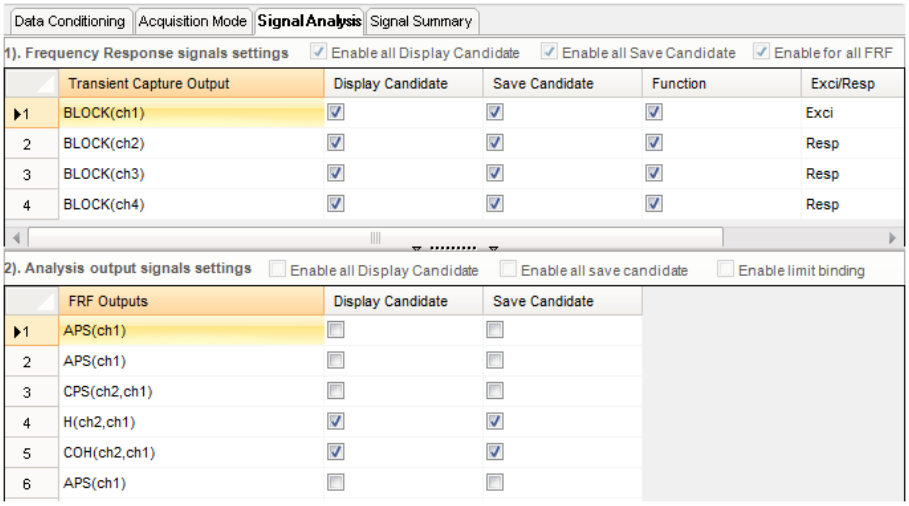
■ Figure 102. CSA Editor Wizard Acquisition Mode selection.

Select the Signals to Compute

The Signal Analysis tab in the CSA Editor is the area to enable which signals will be computed. You can change all the names of the signals. By default, the following signal name conventions are used:

CHn: the native raw data, in the form of a time stream, of nth input channel
BLOCK(chn): the block captured signal of the nth input channel
APS(x): the auto power spectrum of time stream x
CPS(y,x): the cross power spectrum of excitation x and response y
COH(y,x): the coherence function of the excitation x and response y

FRF(y,x): the FRF of excitation x and response y
APS(x): the auto power spectrum of time stream x



■ Figure 103. CSA Editor Wizard Signal Analysis signal selection.

In this setting, the signals set as *Display Candidates* will be selectable for display on CoCo; only the signals that are set as *Save Candidates* will be selectable for Save on CoCo. You should only enable the minimum necessary signals that are required in order to conserve DSP resources and simplify the user interface. Enabling too many signals will make the user interface more complicated to navigate than is necessary.

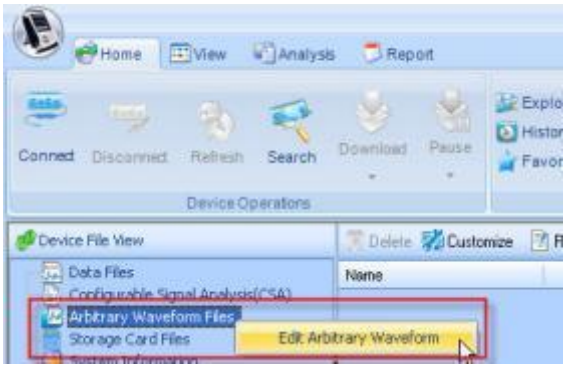
For FRF or cross power computation, you must designate one channel as excitation channel. Once this channel is designated, the other channels will be set as response channels automatically.

For cross channel signals, the default signal names always follow the convention (y,x) where y measures the system response and x the excitation. All signals can be edited in the CSA Editor.

Editing an Arbitrary Waveform

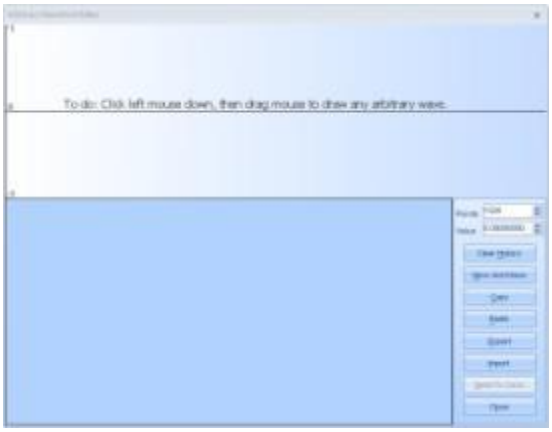
The CoCo output channel can generate an arbitrary waveform which can be programmed on the EDM software. To create an arbitrary waveform you must edit it in the EDM software and then upload it to the CoCo hardware. The waveforms can either be imported from a text file, or drawn by hand.

In the EDM software, right click on "Arbitrary Waveform Files" to open the Arbitrary Waveform Editor



■ Figure 104. Edit arbitrary waveform in EDM software.

To draw a waveform by hand click and hold the mouse button then draw the desired Arbitrary waveform on the top half of the window.



■ Figure 105. Arbitrary waveform editor in EDM software.

After the waveform is completed, the value of each point can be changed by entering the value in the box.

New Arb Wave - creates a blank pane for another arbitrary waveform.

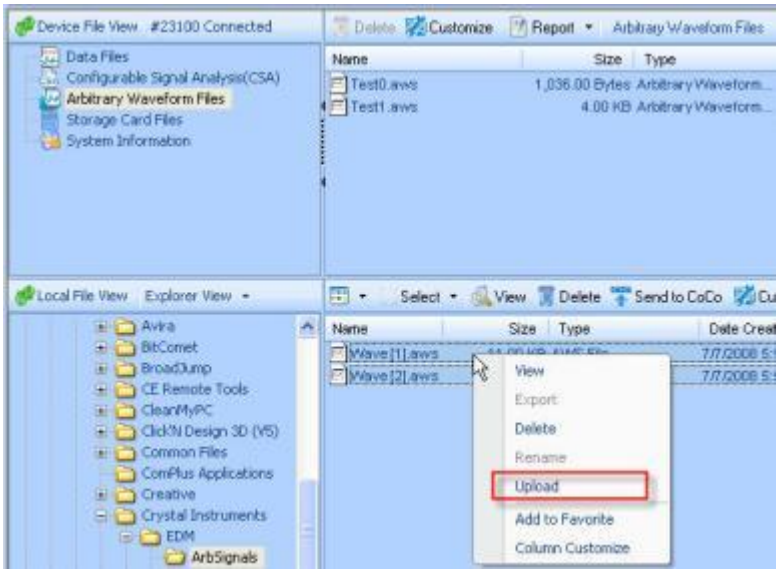
Copy and Paste let you copy the current waveform into a new waveform.

Export lets you save the arbitrary waveform as a text file which can be opened in a text editor or spreadsheet.

Import lets you import an arbitrary waveform that is saved as a text file.

You can also right click on the name of waveform. This opens a pop up menu with copy, paste delete, export and import.

Finally Right click on the arbitrary waveforms and upload them. Then the arbitrary waveforms are ready to be output in CoCo.



■ Figure 106. Upload the arbitrary waveform to the CoCo hardware.

Finally click on the Send to CoCo button to save the arbitrary waveform file on the CoCo hardare.

Validation

After the CSA Wizard is complete and the CSA file is created, connect the host PC to the CoCo device and press the Validate icon to validate the CSA. It may take a few minutes to finish the validation.

The validation process analyzes the CSA file for internal consistency and estimates the required DSA resources required to run the CSA file on the CoCo device.

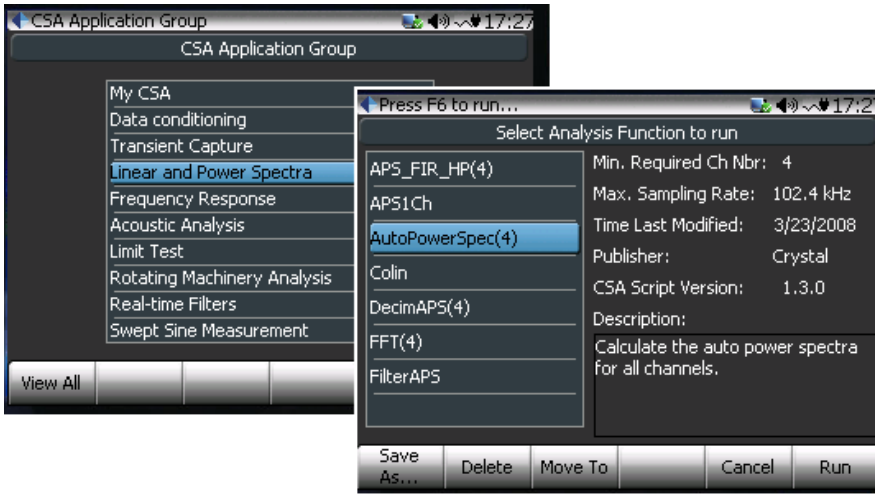
If the Validation passes, then press *Send to CoCo* command in the Validation dialog box to send the CSA project file to CoCo. Alternatively you can manually upload it to CoCo. The CSA uploaded will be classified into different CSA Application Groups based on the template that was used.

CoCo-80 Operation for Spectral Analysis

This section describes the operations of CoCo that are specifically related to the FFT spectral analysis. For general operations of CoCo, refer to previous Chapters of this manual.

Select a CSA Project

To run a spectral analysis CSA press the Analysis button and select either the Linear and Power Spectra or the Frequency Response Application group, then select one of the CSA spectral analysis projects.



- Figure 107. CoCo Select Analysis Function selection display.

Set Analysis Parameters for Spectral Analysis

To set the parameters for spectral analysis, press the Param. Button in the signal display window, select Analysis Parameters, then set the parameters.

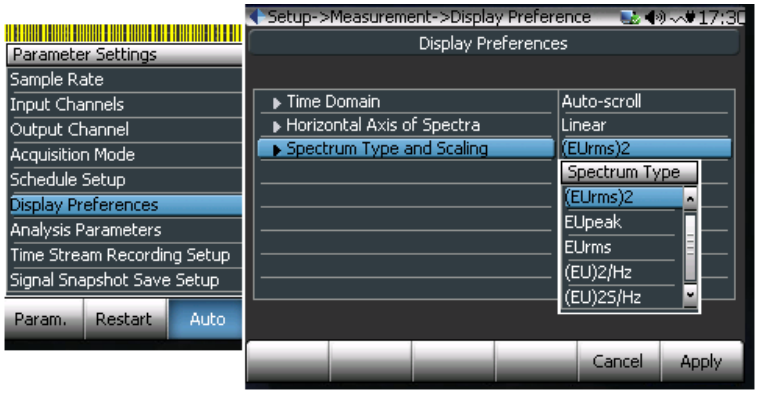
■ Figure 108. CoCo Analysis Parameters selection display.

Block Size: the block size of the time block signals.
Average Mode: Exponential, Linear or Peak Hold applied to frequency domain, power spectra averaging. Time Linear and Time Exponential applies to time domain averaging.
Average Number: the Average number of linear averages. When exponential average is selected as the average mode, 1/(Average Number) is used as the exponential factor.
Window Type: type of data window.

The selection candidates of these fields are defined in the CSA Editor. That is, the maximum sampling rate, maximum number of input channels, etc are defined when you create the CSA. For example if you select a Maximum Sampling Rate of 1 kHz in the CSA Editor then higher sampling rates will not be available on the CoCo device. If a higher sampling rate is required then you must modify the CSA and download it to the CoCo. Although this behavior may seem limiting, it should be noted that it allows the user to choose exactly the analysis functions and optimize the performance of the CoCo device to suit your specific needs and is one of the unique features of the CoCo system.

Set the Spectrum Type

To set the Spectrum type, select the *Display Preferences* under the *Param.* Button and choose from the list.

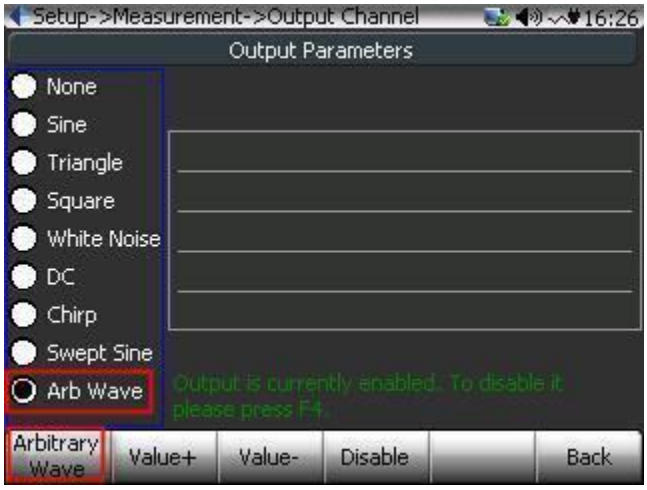


■ Figure 109. CoCo. Spectrum Type selection display.

Set the Output Channel Parameters

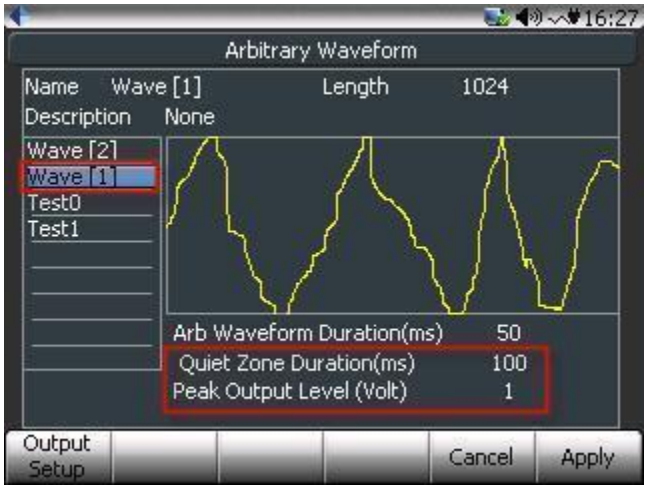
To enable the output channel as a function generator select Output Channel from the Param. Button. Next select the waveform. To set the amplitude and frequency and other parameters move the cursor to the parameter and press the Enter Button to edit the parameter.

To select an arbitrary waveform first select Arb Wave as the output type, then press the Arbitrary Wave Button to choose from all the wave files that are loaded on the CoCo.



■ Figure 110. Output parameters.

Select the waveform from the list on the left and use the Arrow Buttons to move the cursor to the quiet zone, duration and peak output level settings on the right. Press the Enter Button to edit any of these parameters.

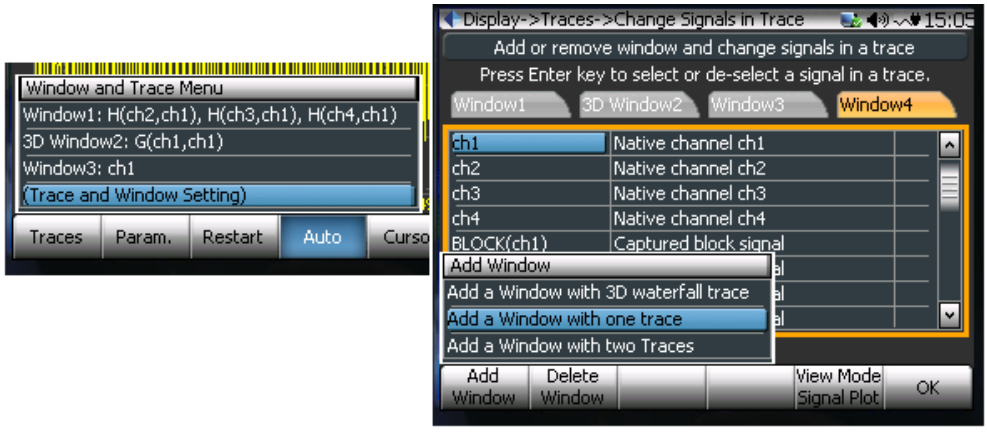


■ Figure 111. Arbitrary waveform settings.

To start the output channel press the Enable Button.

Create Display Window and Set up the Trace

To create a display window select Trace and Window Setting under the Param. Button. Use the soft buttons to add or delete a window, clear the signals from the current window, select all signals or change the view mode to show a numerical value. Change the signals in each window by selecting a specific window tab with the left or right buttons then editing the window settings.



■ Figure 112. CoCo Add Window display.

dB and Linear Magnitude

Most often, amplitude or power spectra are shown in the logarithmic unit decibels (dB). Using this unit of measure, it is easy to view wide dynamic ranges; that is, it is easy to see small signal components in the presence of large ones. The decibel is a unit of ratio and is computed as follows.

$$dB = 10\log_{10}(Power/Pref)$$

where Power is the measured power and P_{ref} is the reference power.

Use the following equation to compute the ratio in decibels from amplitude values.

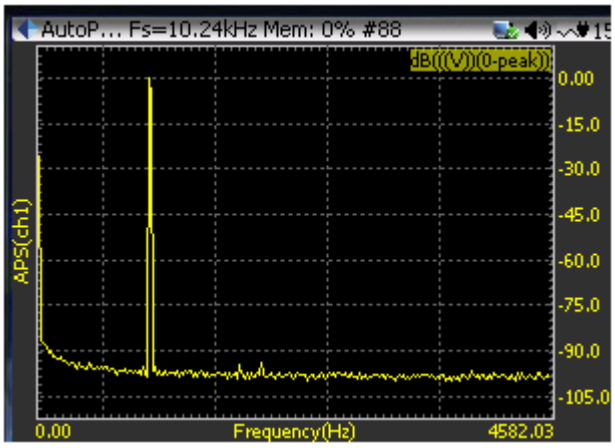
$$dB = 20\log_{10}(Ampl/A_{ref})$$

where Ampl is the measured amplitude and A_{ref} is the reference amplitude.

When using amplitude or power as the amplitude-squared of the same signal, the resulting decibel level is exactly the same. Multiplying the decibel ratio by two is equivalent to having a squared ratio. Therefore, you obtain the same decibel level and display regardless of whether you use the amplitude or power spectrum.

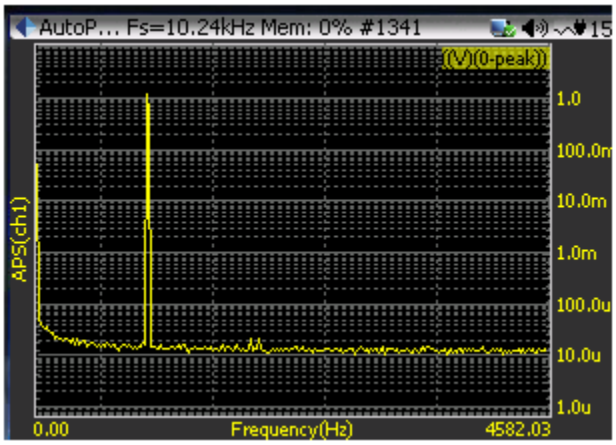
As shown in the preceding equations for power and amplitude, you must supply a reference for a measure in decibels. This reference then corresponds to the 0 dB level. Different conventions are used for different types of signals. A common convention is to use the reference 1 Vrms for amplitude or 1 Vrms squared for power, yielding a unit in dBV or dBVrms. In this case, 1 Vrms corresponds to 0 dB. Another common form of dB is dBm, which corresponds to a reference of 1 mW into a load of 50 Ω for radio frequencies where 0 dB is 0.22 Vrms, or 600 Ω for audio frequencies where 0 dB is 0.78 Vrms.

The picture below shows a sine wave with 1V amplitude displayed in dB. Because the reference is 1Vpk , it shows the peak value of this sine wave as 0dB.



■ Figure 113. Show a 1Vpk sine signal in frequency domain with dB scaling.

Another display format is called Log, or LogMag. The Log display shows the signal scaled logarithmically with the grid values and cursor readings in actual engineering value. The picture below shows the same signal in LogMag.



■ Figure 114. A 1Vpk sine signal in frequency domain with LogMag scaling.

When dB reference is not specified, the dB reference is 1.0 engineering unit. In acoustics application, the dB reference for the sound pressure value is set to 20uPa. The same input signal will result in different dB readings when dB reference is changed.

Set Acquisition Mode

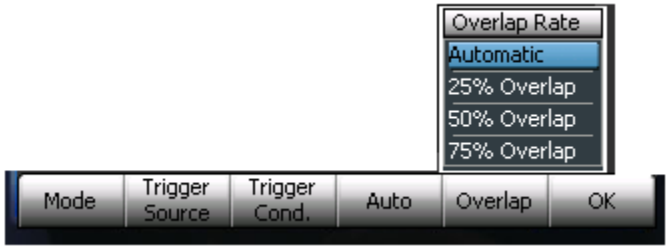
The appropriate acquisition mode should be set to transform the time streams into blocks. The details of acquisition mode for transient capture are described in the next chapter, *Transient Capture and Hammer Test.*

For frequency analysis that use stable and continuous excitation signals, use either *Free-Run* or *Continuous after Trigger mode* in the Acquisition Mode selection.

For details about setting the acquisition mode, refer to the Basic Operation of CoCo-80.

Set Overlap Ratio

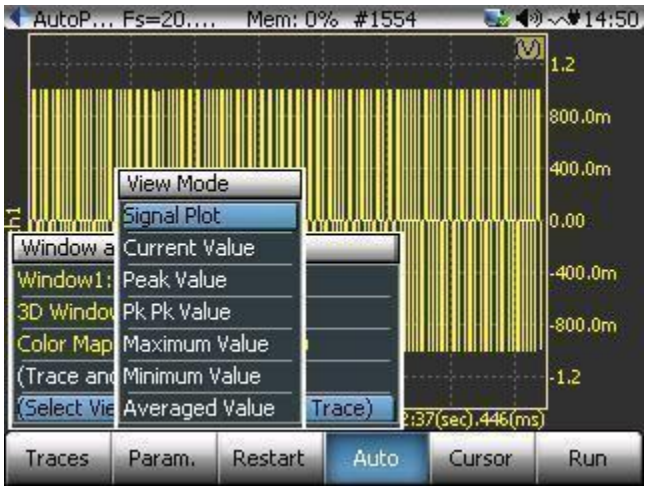
The overlap ratio is set in the Acquisition Mode. The overlap ratio setting will only be effective when the Mode is selected as Free-run or Continuous after Trigger. For triggered transient capture, there will be gaps between frames and an Overlap Ratio can not be applied.



■ Figure 115. Overlap Rate selection.

Select the View Mode

The View Mode defines how the data will be displayed on the screen. To change the view mode select View Mode for Current Trace under the Param. Button.



- Figure 116. View mode.

Signal Plot displays a graph of the plot vs. time or frequencies.

Current Value shows a numerical display of the current value of the signal.

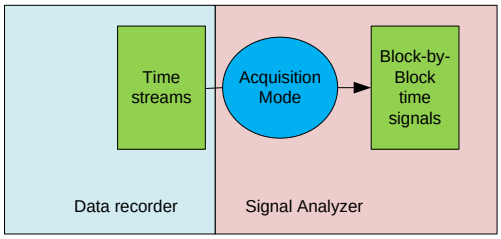
Peak Value, Pk Pk Value, Maximum Value, Minimum Value and Averaged Value show a numerical display of the results of the current data block.

5. TRANSIENT CAPTURE AND HAMMER TESTING

This chapter will demonstrate how to use CoCo to conduct hammer testing. Hammer testing refers to impact or bump testing that is conducted using an impact hammer to apply an impulsive force excitation to a test article while measuring the response excitation from an accelerometer or other sensor. This type of measurement is a transient event that usually requires triggering, averaging and windowing. First, let's briefly review the Transient Capture function on CoCo.

Transient Capture

Transient Capture is one of the most common used functions for dynamic data acquisition. In CoCo the Transient Capture is implemented by setting up the Acquisition Mode. Acquisition Mode defines how to transform the time streams into block by block time signals. It sets the trigger and the overlapping processing. Before the Acquisition Mode stage, the instrument acts as a data recorder while after the Acquisition Mode, it is acts as a signal analyzer.



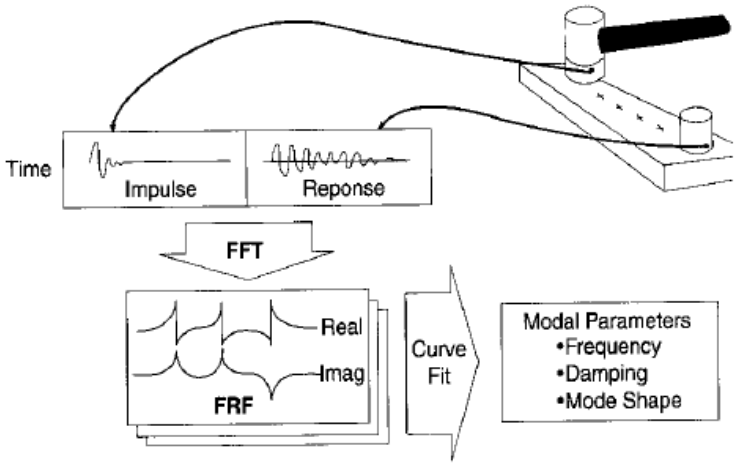
■ Figure 117. Transient capture operation on CoCo.

Besides Acquisition Mode, you must first enable at least one time stream as a trigger candidate in the CSA Editor. Trigger candidates are those time streams that can be selected as a trigger source. The names of these trigger candidates will be passed to the CoCo. During runtime, one of the trigger source candidates must be selected as the trigger source.

Impact Hammer Testing

Typically impact hammer testing is conducted with a signal analyzer to measure FRFs of the device under test. The FRFs can be used to determine the modal properties of the device such as the natural frequencies and damping ratios. In addition the data can be exported to third party modal analysis software to compute mode shapes.

An impact hammer test is the most common method of measuring FRFs. The hammer imparts a transient impulsive force excitation to the device. The impact is intended to excite a wide range of frequencies so that the DSA can measure the vibration of the device across this range of frequencies. The bandwidth or frequency content of the excitation input depends on the size and type of impact hammer that is used. The dynamic force signal is recorded by the DSA. After the impact, the device vibrations are measured with one or more accelerometers or other sensor and recorded by the DSA. The DSA then computes the FRF by comparing the force excitation and the response acceleration signals. Impact testing is depicted in Figure 118.

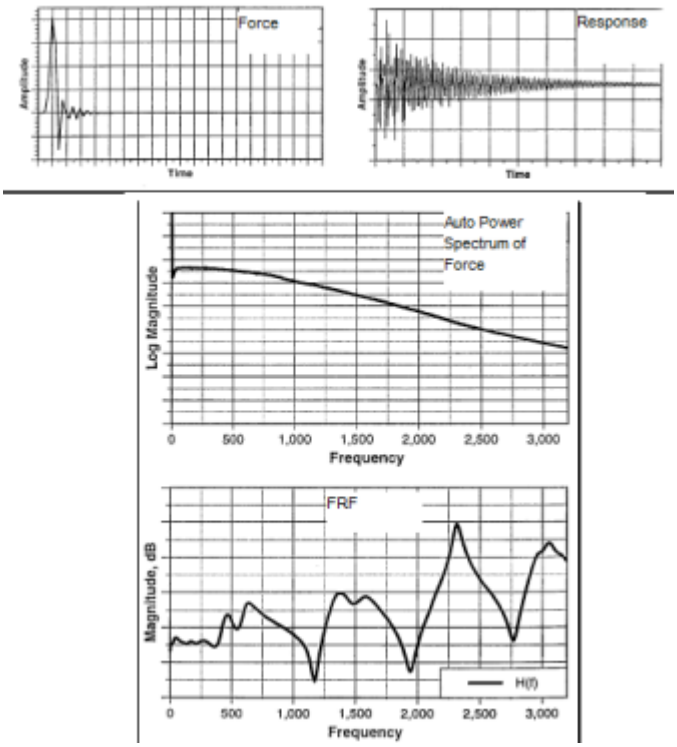


■ Figure 118. Illustration of a typical impact test and signal processing.

The following equipment is required to perform an impact test:

1. An impact hammer to excite the structure. With CoCo we recommend using an impact hammer with IEPE output, which allows the hammer to be connected directly to the analyzer without extra signal conditioning.
2. One or multiple accelerometers that are fixed on the structure. Again, IEPE accelerometers can be used directly with CoCo without additional signal conditioning.
3. Coco Signal Analyzer
4. The CoCo can be used to extract the resonance frequencies and damping factors of the structure. In addition third party software can be used to extract modal shapes and animate the vibration modes.

A wide variety of structures and machines can be impact tested. Of course, different sized hammers are required to provide the appropriate impact force, depending on the size of the structure; small hammers for small structures, large hammers for large structures. Realistic signals from a typical impact test are shown in Figure 10.



■ Figure 119. Typical impact test data. Top left shows excitation force impulse time signal, top right shows response acceleration time signal and bottom shows FRF spectrum.

Impact Test Analyzer Settings

The following settings are used for impact testing.

1. **Trigger Setup** including trigger level and pre-trigger delay are used to capture the transient signal for FRF processing. It is important to capture the entire short transient signal it in the sampling window of the FFT analyzer. To insure that the entire signal is captured, the analyzer must be able to capture the impulse and impulse response signals *prior to the occurrence of the impulse* with the pre-trigger.

2. **Force & Exponential Windows**. Two common time domain windows that are used in impact testing are the force and exponential windows. These windows are applied to the signals after they are sampled, but before the FFT is computed in the analyzer.

   The *force window is used to remove noise* from the impulse (force) signal. Ideally, an impulse signal is non-zero for a small portion of the sampling window, and zero for the remainder of the window time period. Any non-zero data following the impulse signal in the sampling window is assumed to be measurement noise. CoCo has a unique way to implement the force window. This was discussed in the data windowing section in the previous chapter.

   The exponential window is applied to the impulse response signal. The *exponential window is used to reduce leakage* in the spectrum of the response.

3. **Accept/Reject**: Because accurate impact testing results depend on the skill of the operator, FRF measurements should be made with **averaging**, a standard capability in all modern FFT

analyzers. FRFs should be measured using at least 4 impacts per measurement. Since one or two of the impacts during the measurement process may be bad hits (too hard causing saturation, too soft causing poor coherence or a double hit causing distortion in the spectrum), an FFT analyzer designed for impact testing should have the ability to accept or reject the result of each impact after inspecting the impact signals. An *accept/reject* capability saves a lot of time during impact testing since you don't have to redo all measurements in the averaging process after one bad hit.

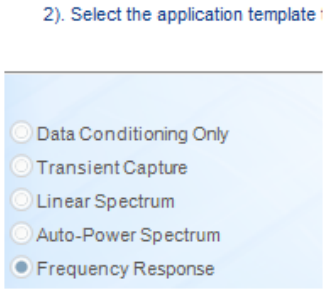
4. **Modal Damping Estimation**. The *width of the resonance peak* is a measure of modal damping. The resonance peak width should also be the same for all FRF measurements, meaning that *modal damping is the same in every FRF measurement*. A good analyzer should provide an accurate damping factor estimate. CoCo uses a curve fitting algorithm to estimate the damping factor. The algorithm reduces the inaccuracy caused by the poor spectrum resolution or noise.

5. **Modal Frequency estimation**. The analyzer must provide capability of estimating the resonance frequencies.

CSA Editor Operation for Transient Capture

This section describes the operation of the CSA Editor that is related to transient data capture and impact testing. For general operation of the CSA Editor, refer to the CSA User's Manual.

In the CSA Editor Wizard, select one of the templates that contain the data transient capture capability. Transient Capture is available in the following templates: *Transient Capture*, *Linear Spectrum*, *Auto-Power Spectrum* and *Frequency Response*.

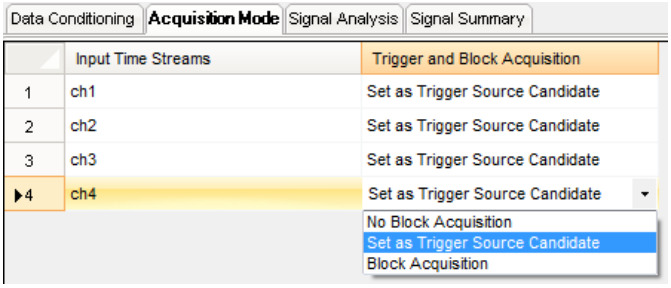


■ Figure 120. CSA Editor Wizard template selection.

The *Data Conditioning Only*, *Octave Analysis*, *Order Tracking* and *Swept Sine* templates do not use regular transient capture to acquire the data.

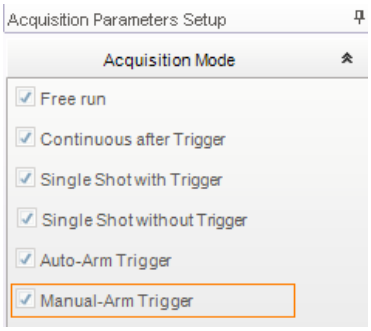
After the Wizard is finished and data conditioning is applied as necessary, go to Acquisition Mode to define the Trigger and Block Acquisition settings and the Acquisition Mode.

At least one input time stream must be selected as the *Set as Trigger Source Candidate*. The items enabled as trigger source CAN BE SELECTED as trigger source when this CSA project runs on CoCo. Notice that the time streams after the data conditioning can also be selected as trigger candidates. Also note that items not specified as trigger candidates can not be used as triggers on the CoCo without modifying the EDM script and downloading it to the CoCo.



■ Figure 121. CSA Editor Wizard Acquisition Trigger and Block Acquisition settings.

To acquire the data block by block, enable the appropriate acquisition modes. For a hammer test, you must enable *Manual-Arm Trigger* which will activate "*Accept/Reject*" logic when a block of signals are captured on CoCo.



■ Figure 122. Acquisition Mode selection.

You must validate and upload the CSA to CoCo after editing.

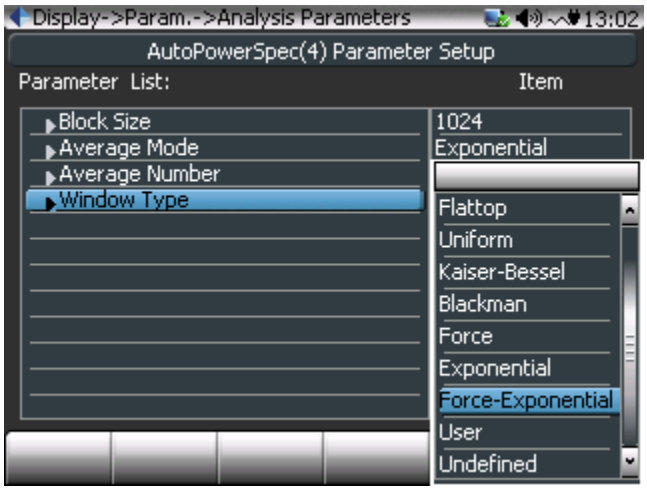
CoCo Hardware Operation for Transient Capture

Select a CSA Project

This section discusses the CoCo settings that are specifically related to transient capture applications. For a complete explanation of these settings refer to the Basic CoCo Operation section. To run a Transient Capture CSA press the Analysis button and select a CSA Application Group that includes transient capture option. These include: Transient Capture, Line and Power Spectrum, and Frequency Response. Then choose an Analysis Function from the CSA files on the CoCo to run.

Analysis Parameters - Window Type

First you must specify the Analysis Parameters under the Param. Button. Select the averaging mode, averaging number and data window type. Transient Capture commonly uses the Force, Exponential or combination Force-Exponential data window function. Press the Apply button to accept the settings.

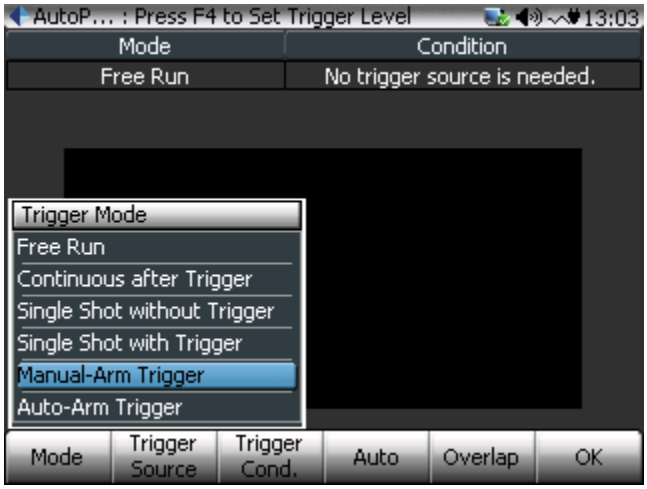


■ Figure 123. Select the data window type for transient capture.

Acquisition Mode

Next select Acquisition Mode under the Param. Acquisition Mode controls how the data is acquired and under what conditions. It includes setting the trigger mode, trigger source, level, conditions and overlap.

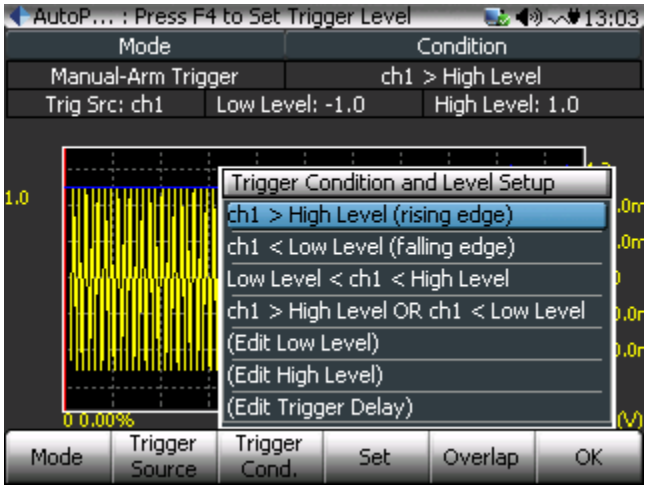
Select Trigger Mode using the Mode Button. Transient capture projects such as impact hammer tests typically use Manual-Arm Trigger or Auto-Arm Trigger. Auto-Arm automatically accepts the data frame into the average and prepares the trigger for the next signal. Manual-Arm provides a graphical display of the data and allows you to accept or reject the frame into the average.



■ Figure 124. Trigger Modes for Transient Capture.

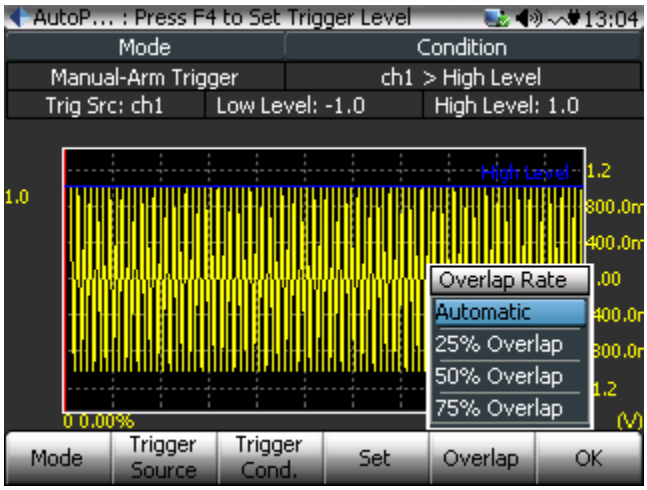
Trigger Source defines which signal to use as the trigger source. Only signals specified in the CSA script are available as trigger sources. If a signal is not available then it can be added as a trigger source by editing the CSA file and downloading it to the CoCo hardware.

The Trigger Condition and Level Setup define the conditions that will trigger the acquisition. You can also edit the high and low level and the trigger delay. Alternatively you can change the level settings with the up and down arrow buttons.



■ Figure 125. Trigger conditions and level setup for transient capture.

Overlap defines the amount of overlap between frames for averaging to reduce the time required to acquire a large number of averages.

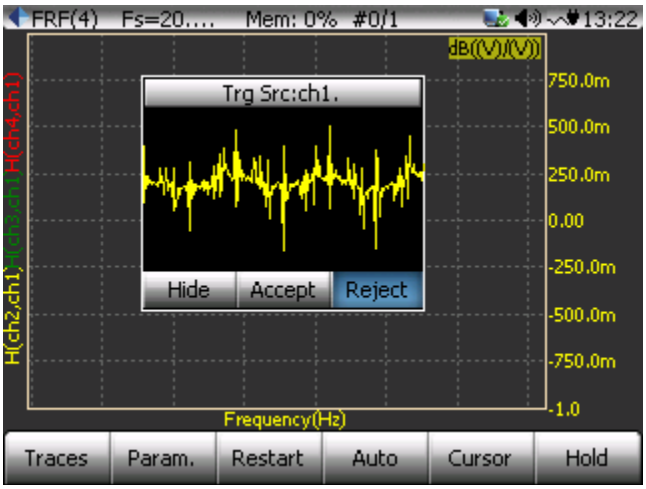


■ Figure 126. Overlap rate for transient capture.

After the Parameter Settings are specified the CoCo begins to wait for a trigger event. A window displays the time elapsed before a trigger event is detected.

■ Figure 127. Waiting for trigger message.

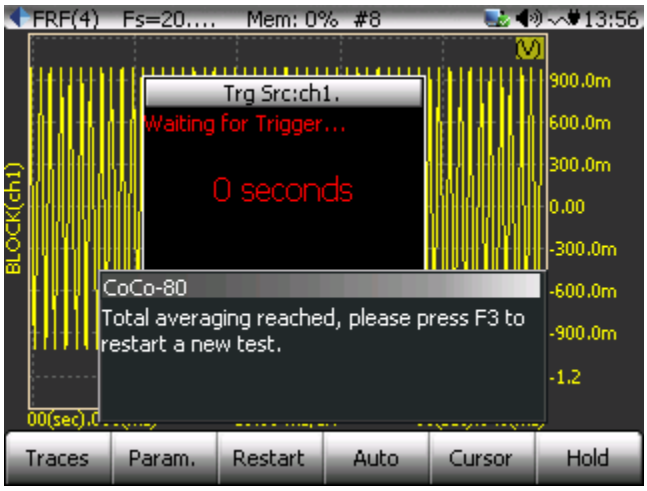
When a trigger event is detected and Manual-Arm Trigger is selected, then a small window will show the data frame and give you the option to accept or reject the data. Accept will include the frame into the average and then ask you to proceed to the next trigger by pressing the Next button. Reject will discard the frame, not include it in the average and return to the waiting for trigger mode. If Auto-Arm Trigger mode is selected then the system will automatically return to the wait mode after each trigger event with no user intervention.



■ Figure 128. Accept/Reject display for transient capture.

The frame average number is displayed in the status bar to help you monitor how many averages have been recorded. When the averaging mode is set to linear and you reached the averaging number you are prompted to restart a new test by pressing the Run Button.

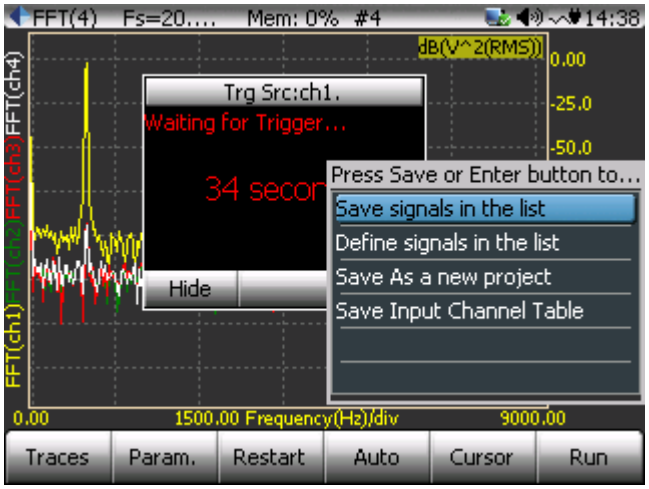
When the averaging mode is set to exponential then new frames will be acquired and included in the average until you press the Hold Button. The system does not stop when the average number reaches the averaging number. The averaging number only defines the behavior of the averaging function. Exponential averaging is intended for continuous averaging to help observe how a signal changes over time or converges to a mean.



- Figure 129. When averaging is complete you can restart a new test with the Run Button.

Save Averaged Data

Data can be saved at any time by pressing the Save Hardware Button. This opens a menu with several options. Press the Save Button again to save the signals in the save list. This can be done in the middle of an average or at the end.



- Figure 130. Save data by pressing the Save hardware button.

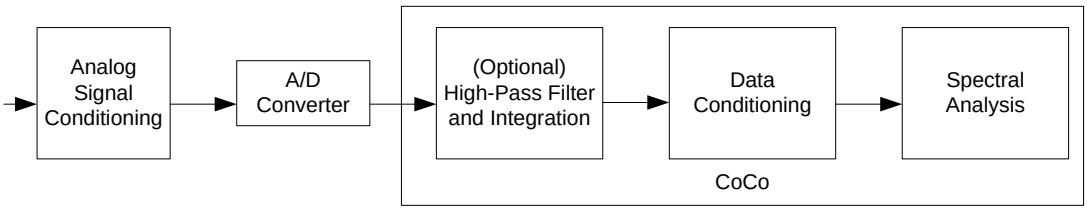
Select Define signals in the list to add or remove signals from the save list or setup automatic data save feature.

6. BUILT-IN DIGITAL INTEGRATION AND FILTERING

Introduction to Digital Integration

Ideally a measurement is made using a sensor that directly measures the desired quantity. For example an accelerometer should be used to measure acceleration, a laser velocimeter pr velocity pickup should be used to measure velocity and an LVDT should be used to measure position. However since position, velocity and acceleration are related by the time derivatives it should be possible to measure an acceleration signal and then compute the velocity and position by mathematical integration. Alternatively you can measure position and compute velocity and acceleration by differentiating. The integration can be performed at the analog hardware level or at the digital level.

The CoCo provides a means to digitally integrate or double integrate the incoming signals. The integration module fits into the very first stage after data is digitized, as shown below:



There are several issues to address in such implementation:

1. The integration and double integration algorithm has to be accurate enough and it must find a way to reduce the effects of a DC offset. A tiny initial value, offset in the measurement or temperature drift before the integration, may result in a huge value after single or double integration. This DC effect can be removed using a high-pass filter.

2. The initial digital signal must have a high signal to noise ration and high dynamic range. The integration process in essence will reduce the high frequency energy and elevate the low frequency components. If the original signals do not have good signal noise ratio and dynamic range, the signals after integration and double integration will have too much noise to use. The noise will corrupt the integrated signal.

3. The instrument must be able to set two different engineering units: one engineering unit for the input transducer and a second engineering unit after the integration. For example, first the instrument must provide a means to set the sensitivity of the sensor, say 100*mV/g*. After the double integration the instrument must have the means to set the engineering unit to a unit that is compatible with the integration such as *mm*.

The CoCo instrument handles these three issues effectively so you can get reliable velocity or displacement signals from the acceleration measurement, or displacement signals from the velocity measurement. The CoCo hardware has a unique design to provide 130dB dynamic range in its front-end measurement. The signals with high dynamic range will create better results after digital integration.

Since such build-in integration is conducted in the time domain before any other data conditioning or spectral analysis, the time streams generated after the digital integration can be treated in the same way as other time streams. They can be analyzed or recorded.

CoCo also provides differentiation and double differentiation to calculate the acceleration or velocity from velocity or displacement transducers. Differentiation is not as common as integration.

It must be noticed that the displacement after double integration to the acceleration is not the same as that measured by a proximity probe. A proximity probe measures the relative displacement between an moving object to the fixed coordinates seated by the probe. The accelerometer and its integration value can only measure the movement of the moving object against the gravity field.

Sensor Consideration

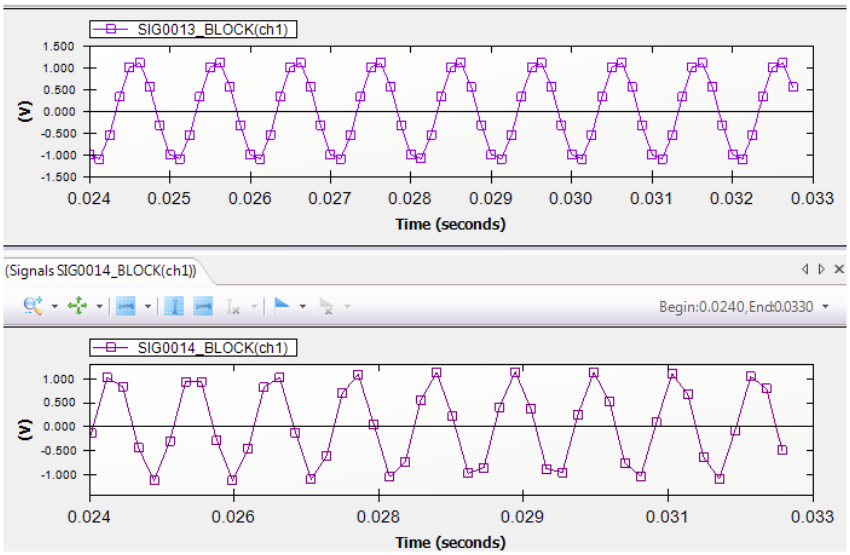
Accelerometer signals that are non-dynamic, non-vibratory, static or quasi-static in nature (low acceleration of an automobile or flight path of a rocket) are typically integrated in the digital domain, downstream of the signal conditioner. Piezoelectric and IEPE accelerometers are commonly used to measure dynamic acceleration and, therefore, dynamic velocity and displacement. They should not be used to measure static or quasi-static accelerations, velocities, or displacements because the IEPE includes analog high pass filtering in the sensor conditioning that cuts out any low frequency signal. At frequencies approaching 0 Hz, piezoelectric and IEPE accelerometers cannot, with the accuracy required for integration, represent the low frequency accelerations of a test article.

When this slight inaccuracy is integrated in order to determine velocity and displacement, it becomes quite large. As a result, the velocity and displacement data are grossly inaccurate. A piezoresistive or variable-capacitance accelerometer is a better choice for low frequency signals and for integration. These types of sensors measure accelerations accurately at frequencies approaching 0 Hz. Therefore the integration calculation of velocity and position can be used to produce accurate results.

Calculation Errors in Digital Integration

Two types of calculation errors can be caused by digital integration: low sampling rate and DC offset.

The sampling rate of a signal must be high enough so that the digital signal can accurately depict the analog signal shape. Some people may think that according to the Nyquist sampling theorem as long as the sampling speed is more than twice of the frequency content of the signals before the integration, the integration results should be acceptable. This is not true. Satisfying the Nyquist frequency only ensures an accurate estimate of the frequency of a measurement. Integration error can still occur of a signal is not sampled at more than twice the signal frequency. Figure 131 shows a 1kHz sine wave sampled at 8kHz and 5.12kHz.

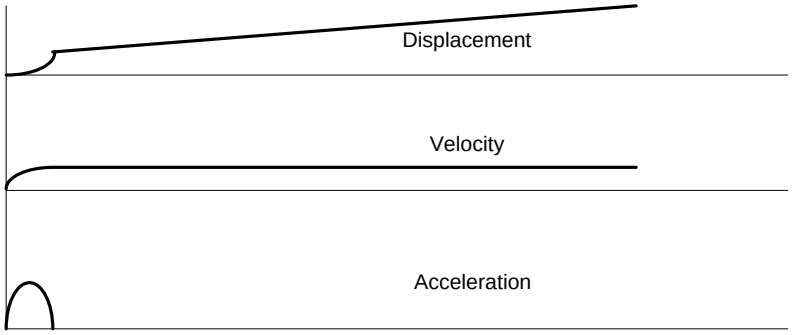


■ Figure 131. A 1 kHz sine wave sampled at 8 kHz (top) and also sampled at 5.12 kHz (bottom).

It is clear that the higher the sampling frequency, the closer this digitized signal is to the true analog waveform. When the sampling rate is low, the digital integration will have significant calculation error. For example the 5.12 kHz sampled signal is not symmetric about 0 volts so the integration will drift and a double integration may grow with accumulated error very fast.

In general, you should use a sampling rate 10 times higher than the frequency content that is of interest in the signal when you apply numerical integration.

DC offset is the second type of digital integration error and can be more severe. It is caused by any measurement error before integration and may result in huge amplitude errors after the integration. Figure 132 shows how a small measurement error in acceleration will create a constant DC offset in the acceleration integrated to compute velocity and result in a drift and eventually an infinite large magnitude of displacement after double integration.



■ Figure 132. A small error in acceleration results in a DC offset in velocity and a huge drift in displacement.

Of course, the computed velocity and displacement signals are unrealistic. They are artifacts of the integration errors. In order to remove such a problem caused by inaccurate measurement and

digital integration, a high pass filter can be applied before or after the integration. It should be noted that the high-pass filter will distort the waveform shape to some extent because it alters the low frequency content of the signal. However this effect must be tolerated if numerical integration is used.

Digital High-Pass Filter

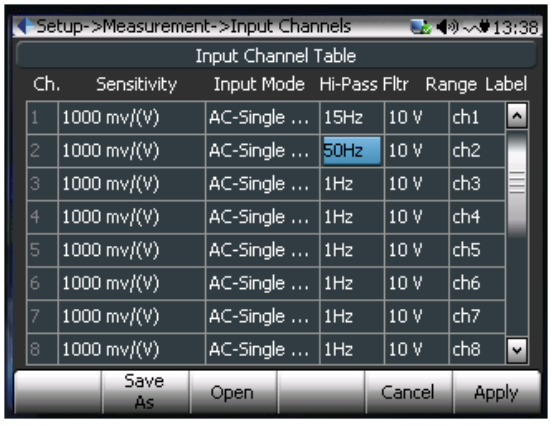
The most effective way to remove the DC drift effect as described above is to apply a high pass digital filter to the continuous time streams. In CoCo, a unique algorithm is realized so that even the data is sampled at high rate, the high pass filter can still achieve very low cutoff frequency.

The filter cutoff frequency is specified at -3dB attenuation.

To remove unwanted signals at or near DC, please set up the cutoff frequency of the digital high-pass filter as high as possible as long as it won't chop off useful frequency content of your interest.

To give an example, if you are not interested in any frequency less than 20Hz, then you can set the cutoff frequency to approximately 10Hz. With this setting, the amplitude attenuation at 20Hz will be less than 1dB.

The following picture shows that ch1 sets the high-pass filter at 15Hz and ch2 at 50Hz. Others are at 1Hz.

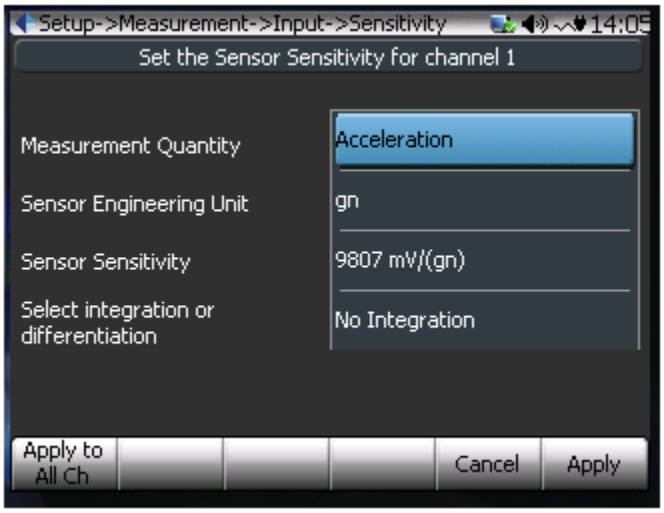

Setup->Measurement->Input Channels
13:38
Input Channel Table
Ch. Sensitivity Input Mode Hi-Pass Fltr Range Label
1 1000 mv/(V) AC-Single ... 15Hz 10 V ch1
2 1000 mv/(V) AC-Single ... 50Hz 10 V ch2
3 1000 mv/(V) AC-Single ... 1Hz 10 V ch3
4 1000 mv/(V) AC-Single ... 1Hz 10 V ch4
5 1000 mv/(V) AC-Single ... 1Hz 10 V ch5
6 1000 mv/(V) AC-Single ... 1Hz 10 V ch6
7 1000 mv/(V) AC-Single ... 1Hz 10 V ch7
8 1000 mv/(V) AC-Single ... 1Hz 10 V ch8
Save As
Open
Cancel
Apply

CoCo-80 Operation

Integration can be enabled in the Input Channel table. In CoCo, to set up the built-in integration or double integration, you must set two engineering units. The first one is for sensor sensitivity; the second for the engineering unit after the integration or differentiation. For example, you can choose either *g* or m/s^2 as the engineering unit used for the accelerometers. After the double integration, you can choose one from the list of *meter*, *cm*, *mm* or other displacement units for displacement presentation.

Example:

First select the Acceleration or Velocity in the input channel table:

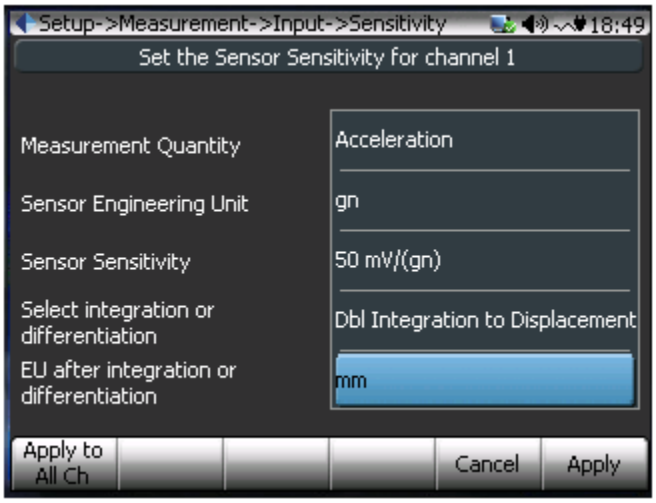


■ Figure 133. Sensor sensitivity without integration.

Then select the engineering unit of the sensor to be used and set its sensitivity.

Under the item of Selection integration or differentiation, select appropriate item. The example shows *Double Integration to Displacement* is selected

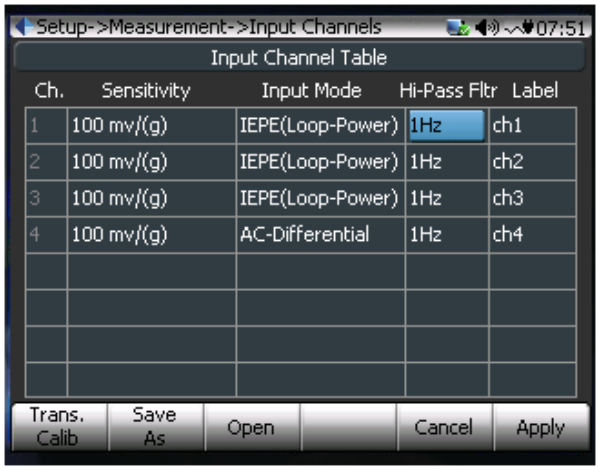
Select the appropriate engineering units for displacement. The example shows displacement units of millimeters.



■ Figure 134. Sensor sensitivity window with double integration and units.

With this setup, the accelerometer is set to measure *g* while the displacement is using *millimeter* as the output unit. The sensor sensitivity 50mV/g transforms the input voltage into *g* appropriately.

To enable or set the high pass filter, simply go to the channel table and high-light the column of ***Hi-Pass Fltr***, and press Enter button. Each channel can have its independent cutoff filter values.

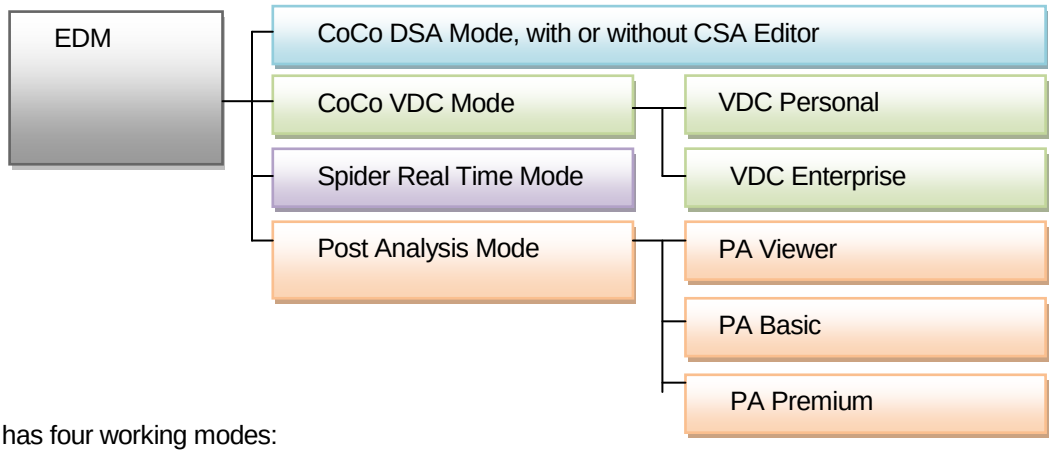


7. EDM PC SOFTWARE

This section briefly describes the Engineering Data Management (EDM) software that is used to download data from the CoCo-80 to a PC, view, analyze and export the data. For details about EDM software installation and operation please refer to EDM User's Manual.

The Engineering Data Management (EDM) is a PC software used for data management, post signal processing, viewing, report and the connection between the Crystal Instruments hardware, the PC and the data storage system. EDM provides connectivity to one or more CoCo or Spider devices. It provides data management tools that allow you to search through many tests, records and view file properties or waveform characteristics. The analysis tools allow you to display data in a wide variety of formats and configurations and let you identify important signal characteristics using cursors. The report tool allows you to document the hardware configuration or data analysis results in a user formatted document.

The basic structure of EDM software is:



EDM has four working modes:

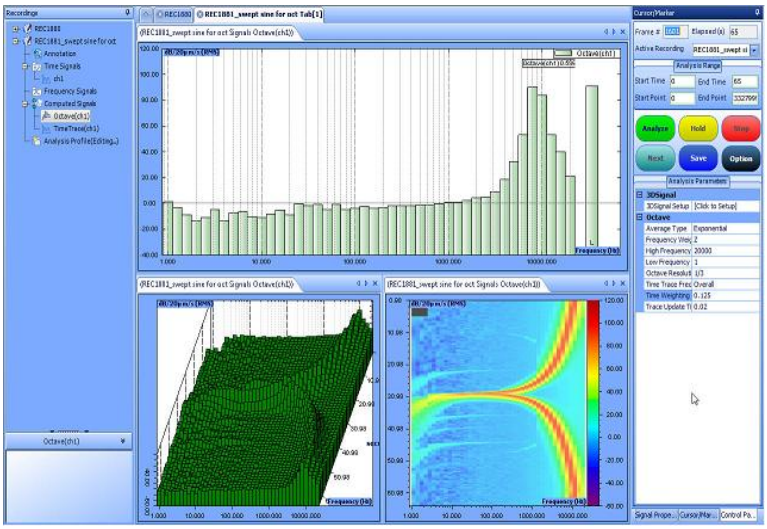
- **CoCo-80 DSA mode**: accesses CoCo-80 in its DSA mode, download files and view data files. CSA Editor, a tool of editing CoCo testing projects, will be included in this mode.

- **CoCo-80 VDC mode**: creates route data collection database, upload settings to CoCo, download data to PC, trending and alarm analysis. There are two versions of VDC modes: personal version allows the user access the database on his local PC. Enterprise version allows multiple user access the database on the LAN.

■ Figure 135: EDM in VDC Mode, Signal Analysis Display

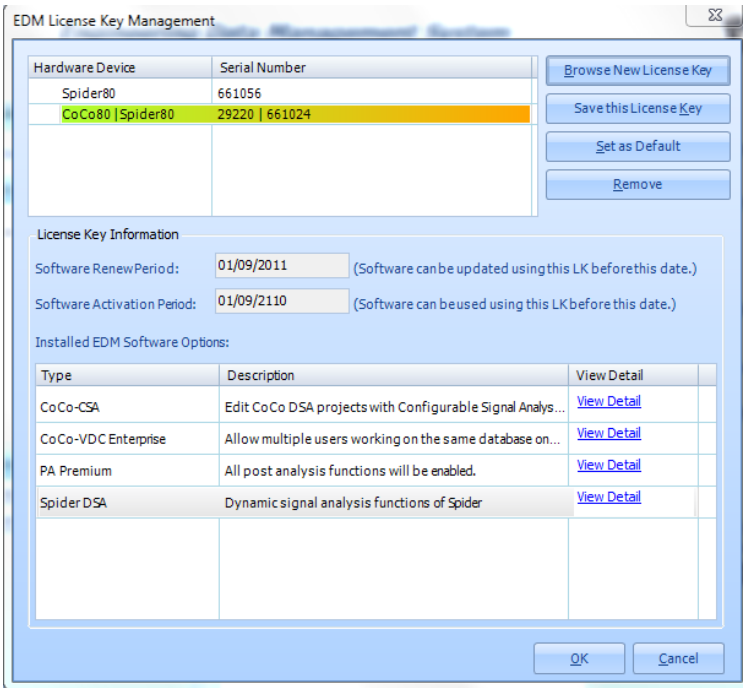
- **Spider Real-Time Mode**: operates on Spider hardware in real-time.

- **Post Analysis Mode**: analyzes the data files on PC using various algorithms. PA has three versions: PA Viewer allows the user to view the data and create report; PA Basic has FFT spectral analysis and 3D signal display functions; PA Premium has all post analysis functions.



EDM software is registered to a CoCo or a Spider device. To activate the EDM software, the user must have a License Key. EDM software uses a License Key file to enable or disable certain functions. License Key is also used to control the Activation Period and Software Subscription Renew period. Multiple License Keys can be installed in one EDM installation. This allows an instance of EDM runs multiple hardware devices.

A typical management page for license keys is shown below:



Software Renew Period: this is the time period that this EDM installation can be upgraded using the current installed License Key. When the time expires, the EDM software will still be functional but cannot be updated.
Software Activation Period: this is the time period that this EDM installation can be used using this License Key.

The CoCo DSA Mode of EDM

The EDM Software functions as both the means of transferring date from the CoCo-80 to the PC and also as a data management and analysis tool. The main features of the software include: transferring data between the CoCo-80 and a PC, viewing, searching and exporting data to other formats and using the analysis tools to measure signal characteristics.

Data Transfer

After a connection is established between the CoCo-80 and a PC, the EDM software manages the transfer of data between the two devices. The data includes recorded time streams, saved signals, and CSA projects. When EDM detects the connection, the software displays a list of the files available for transfer and allows the use to initiate the download to the PC. After files are downloaded they can be deleted from the CoCo-80 flash memory to create free space for new data files.

Data Management

The nature of signal measurement generates a large number of records. The EDM software provides tools to manage this data to simplify searching, review and exporting the data. Data can be searched by key words, date or time, size or other file attributes. Data can be previewed via

thumbnail representations of the data or by text file attributes. Data can be replayed within the search tool including the ability to scroll through a long time stream to verify that the record contains the required properties. EDM simplifies the process of exporting data from the native ASAM ODS format to other popular universal formats including UFF, BUFF and ASCII.

Data Analysis

The EDM software includes basic analysis tools that help measure signal characteristics such as zoom and pan and cursors. Multiple signals can be overlaid on one trace for comparison. Long time streams can be played back and time or frequency data can be displayed.

CoCo-80 – PC Communication

The first step in downloading data from the CoCo-80 to a PC is to establish communication between the two devices. CoCo-80 is equipped with a number of hardware connectivity functions for easy communication with a host PC. These include:

- USB port
- 100MbaseT Ethernet
- Wireless 802.11b/g using SD card

You can choose one of following four typical connections:

- Connect CoCo-80 to a PC directly using a USB cable
- Connect CoCo-80 to a PC directly using Ethernet via cross-over cable
- Connect CoCo-80 to a local network using Ethernet where a host PC resides on the local network
- Connect CoCo-80 to a local network using a wireless SD card

The table below summarized the configuration for these connections.

■ Table 4. PC to CoCo-80 Configuration Summary.

Connection method	CoCo-80 Configuration	Host PC Configuration
Connect CoCo-80 to a PC directly using USB	No special configuration required	Install the EDM host PC software Install the CoCo-80 USB RNDIS Driver
Connect CoCo-80 to a PC directly using Ethernet via cross-over cable	CoCo-80 must be configured with a fixed static IP	Host PC IP must be configured with fixed static IP at the same subnet mask as that of CoCo-80
Connect CoCo-80 to a local network	If DHCP server is installed on the local network, CoCo-80 can obtain	If DHCP server is installed on the local network, host PC can obtain

using Ethernet where a host PC resides on the local network	an IP address automatically. If DHCP server is not installed on the local network, fixed static IP address must be configured on CoCo-80.	an IP address automatically. If DHCP server is not installed on the local network, fixed static IP address must be configured on the host PC. Same subnet mask must be used.
Connect CoCo-80 to a local network using wireless SD card	If DHCP server is installed on the local network, CoCo-80 can obtain an IP address automatically If DHCP server is not installed on the local network, a fixed static IP address must be configured on CoCo-80	If DHCP server is installed on the local network, host PC can obtain an IP address automatically" If DHCP server is not installed on the local network, fixed static IP address must be configured on the host PC. The same subnet mask must be used.

In this table, *DHCP (dynamic host configuration protocol) server* refers to a piece of software installed on the local area network, either wired or wireless, that supports the "Obtain an IP address automatically" function on any networked device. DHCP is commonly used in most office networks.

Transfer Data Files to the Host PC

To transfer the recorded data files to a PC, you must:

1. Establish a physical network connection between the CoCo-80 and a PC. This can be done by using either the Ethernet, USB-client port, or SD wireless card.

2. Execute the EDM software on the PC.

3. Download the data files from the CoCo-80 to PC using EDM software.

The data files will be automatically stored in the ASAM-ODS format. They can be converted into other formats with the EDM software.

Configuring the CoCo-80 Network Settings

CoCo-80 Network Settings must be configured when an Ethernet or SD Wireless card are used for communicating with the host. When USB is used for the connection, this section can be ignored.

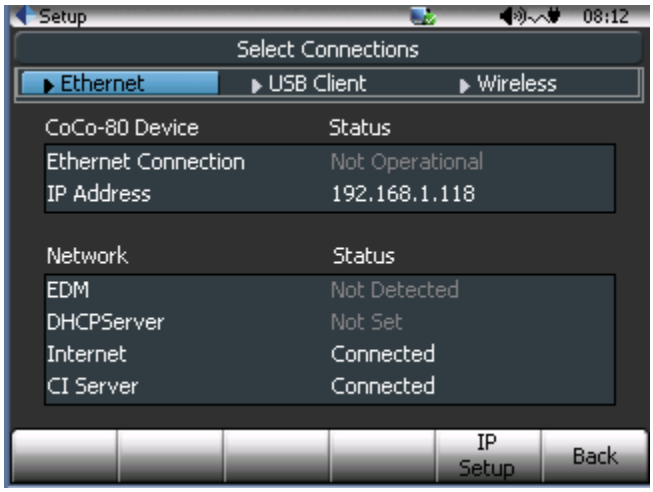
To configure the network settings for the CoCo-80, complete the following steps:

1. Power on the CoCo-80. In the Welcome page, move the focus to IP address and press ENTER.

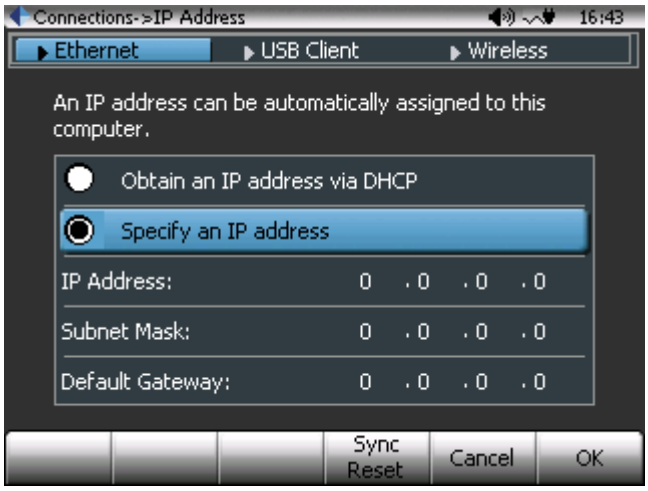
2. In the **IP Settings** window click **Edit the IP settings** to specify a static IP address and subnet mask. Type in the **IP address** and **Subnet mask**. You must specify a static IP address and use a crossover cable to directly connect the CoCo-80 to the host computer. In this case, both the Gateway and DNS server fields must be blank or set to zeroes. If the

network uses a DHCP server and you are not directly connecting the CoCo-80 to the host computer with a crossover cable, click the **Obtain IP address via DHCP server** option button.

3. Click **OK** to apply the changes.



- Figure 136. Ethernet connection status.



- Figure 137. Specify a static IP address for the Ethernet connection.

- Figure 138. USB Connection Status Display.

Access Code: This is a special setup to prevent an unauthorized user from accessing the CoCo-80 on the LAN. It also provides a means for the EDM software to access a particular CoCo-80 on the network. The EDM requires the CoCo-80 Access Code to access it over the LAN.

Configuring the Host PC Network Settings

If the host system is a PC which is only connected directly to the CoCo-80 using a cross over Ethernet cable, you can manually configure the TCP/IP settings. You can also use the "alternate configuration" functionality to maintain seamless operations on both office and private networks without having to manually reconfigure the TCP/IP settings. Choose whichever method best applies to your system configuration and connectivity needs. Refer to the Microsoft support website for more information on "alternate configuration" http://support.microsoft.com/kb/283676.

Note: You must be logged onto the host system as an Administrator in order to change network settings. Contact the system administrator to get access to the necessary privileges.

Connect CoCo-80 to a PC directly using USB client

A USB connection is the easiest method to connect the CoCo-80 to a PC. This requires the following steps:

1. Install the EDM software on the PC. Install the RNDIS USB driver on the PC.

2. Connect CoCo-80 to the PC through the provided USB cable. This cable has a mini-client port connecting to the CoCo-80 and a flat USB port connecting to the PC.

Connect CoCo-80 to a PC directly using Ethernet via cross-over cable

Another way to connect the CoCo-80 to a PC directly is to use the Ethernet port and a CAT-5 cross-over cable. The advantage of using Ethernet compared to USB is that the data transfer speed is faster with Ethernet. The disadvantage is that you must configure the IP settings on the host PC so it can communicate with the CoCo-80.

In this case, both PC and CoCo-80 must be configured with a fixed IP address with the same subnet mask. The host PC can also use the Alternative Configuration feature for convenient communication with its office local area network. Alternate Configuration is a networking option within Windows to maintain seamless operations on both office and home networks without having to manually reconfigure TCP/IP settings. Refer to the Microsoft support website for more information of this feature.

http://support.microsoft.com/kb/283676

Connect CoCo-80 to a local network using Ethernet

In this connection case, if DHCP server is not installed on the local area network, both PC and CoCo-80 must be configured with a fixed IP address with the same subnet mask. If DHCP server is installed, then both the PC and the CoCo-80 can use the **Obtain an IP address automatically** function.

Connect CoCo-80 to a local network using wireless SD card

In this connection case, if DHCP server is not installed in the local area network, both PC and CoCo-80 must be configured with a fixed IP address with the same subnet mask. If DHCP server is installed, both the PC and the CoCo-80 can use the **Obtain an IP address automatically** function.

AmbiCom WL11 or WL54-SDIO Wireless LAN Card is a compact size wireless card for the SDIO capable PDAs and other SDIO compatible mobile computing device using Microsoft Windows Mobile 2003 and Windows Mobile 5.0 operating system. In addition to the slim and ultra lightweight SD design, the Wireless SD Card also features secure data transfer and full privacy, exceptional range and data rate, and meets Wi-Fi certification standards for total interoperability with other 802.11b/g equipment. More information is available at

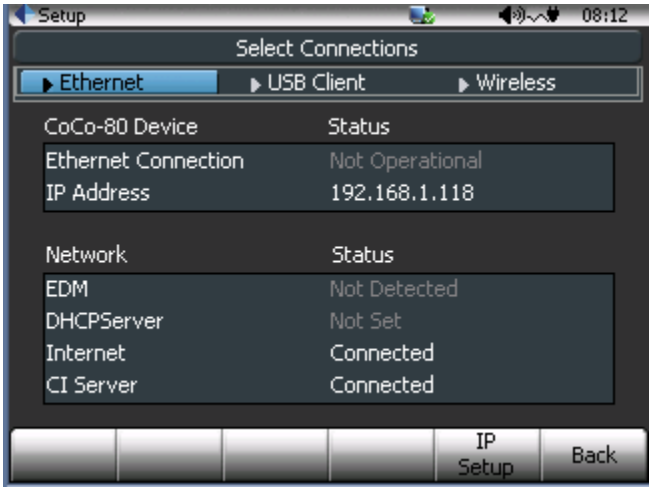
http://www.ambicom.com/products/wave2net/wl54-sdio10.html

Network Connection Diagnosis

The following section describes methods for diagnosing network connectivity from the CoCo-80 or the PC which may be helpful when setting up the network connection.

Diagnosis from the CoCo-80 side

A tool is provided to detect the existing network settings from the CoCo-80 side. Push the Setup button, and select the Connections icon and press the Enter button, the connection status is shown below:



■ Figure 139. Ethernet connection status screen.

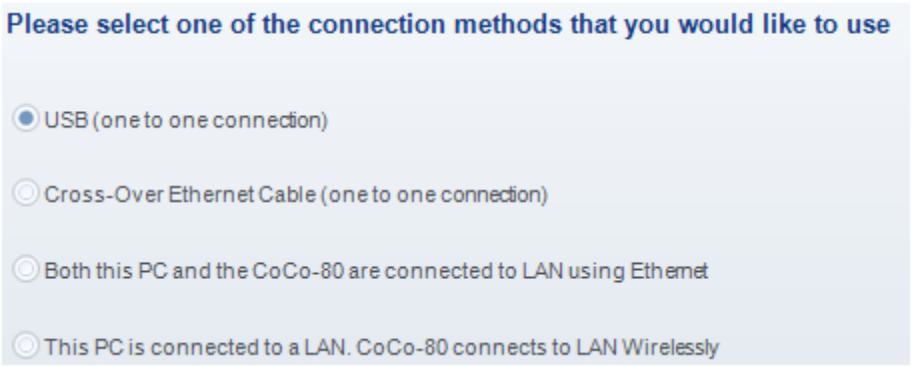
The network setting detection shows the following status:

- Hardware: indicates whether the Ethernet, USB port or Wireless card inside the CoCo-80 device are functional.
- IP Address: indicates the IP address of the CoCo-80.

- DHCP server: indicate whether the CoCo-80 has detected a DHCP server on the local area network.
- EDM: indicates whether CoCo-80 is connected to the EDM, the host software on a PC.
- Internet: indicates whether the CoCo-80 is connected to the Internet.
- CI server: indicates whether the CoCo-80 is detecting the Crystal Instruments server. The CI server is used to host new software to keep the CoCo-80 up to date.

Diagnosis from the PC

The connection between the CoCo-80 and a PC is managed within the EDM software on the PC. The EDM software provides connection diagnosis capability. The Connection Wizard dialog box will show one of following four connection pictures:


Please select one of the connection methods that you would like to use
USB (one to one connection)
Cross-Over Ethernet Cable (one to one connection)
Both this PC and the CoCo-80 are connected to LAN using Ethernet
This PC is connected to a LAN. CoCo-80 connects to LAN Wirelessly

■ Figure 140. EDM network connection status screen.

Select appropriate connection type, and follow the online instructions. The EDM will provide diagnose information.

Data Format

The data format within the CoCo-80 and the EDM software is the ASAM ODS File format. ASAM ODS files have the suffix ATFX. EDM also interfaces to other file formats including NI-TDM, MatLab, UFF, BUFF and user-defined ASCII files.

ASAM ODS (Open Data Service)

The rapid progress in hardware and software leads to storage of data in many different data base systems as well as under different hardware and/or server generations. During development and production of complex products, a huge mass of data is produced. Today, data are stored within the automotive industry in a standardized format specified by the ASAM ODS workgroup. ASAM stands for ***Association for Standardization of Automation and Measuring Systems***, and ODS stands for "Open Data Services". The CoCo-80 uses the ASAM ODS data format as the internal data format and data is saved by default in this format when it is downloaded from the device to a PC.

The ASAM ODS standard has the fundamental quality of storing data with an architecture-independent method. This leads to great advantages when exchanging data between different sources and possible prospective customers.

Many systems in test, evaluation, and simulation environments have their own proprietary formats to store data. These formats usually are very different from each other regarding the description of the configuration (unit under test, test sequence, test equipment, etc.) as well as the way results are stored (database, binary files, etc.).

The main objectives for a standardization of data access interfaces are to reduce costs and risks within projects, and to provide a reliable basis for implementations in the area of data storage and data usage. Using standardized interfaces and common structures minimizes the efforts for the system integration within the heterogeneous environments discussed above and makes it much easier to exchange data.

Because of these benefits the ASAM ODS data format was chosen as the internal format for the CoCo-80 and the EDM software.

UFF Files

The CoCo-80 and EDM Software also support the Universal File format (UFF). This format was originally developed by the Structural Dynamics Research Corporation (SDRC) in the late 1960s and early 1970s to facilitate data transfer between computer aided design (CAD) and computer aided test (CAT) in order to facilitate computer aided engineering (CAE). SDRC, as part of EDS, continues to support and utilize the UF formats as part of their CAE software. Currently, MTS, Noise and Vibration Division supports and continues to develop IDEAS software in the test area that utilizes UF formats.

The formats were originally developed as 80 character (card image), ASCII records that occur in a specific order according to each UF format. As computer files became routinely available, single UF formats were concatenated into computer file structures. Recently, a hybrid UF file structure (UF Dataset 58 Binary) was developed for experimental data that allows data to be stored in a more efficient binary format.

Before the introduction of ASAM ODS, the use of the Universal File Format as a de-facto "standard" has been of great value to the experimental dynamics (vibration and acoustic) community, particularly in the area of modal analysis. Both users and vendors have benefited from this de-facto standard.

The EDM software will be able to export the data into UFF (Dataset 58) and BUFF (Dataset Binary 58). For more information on UFF refer to http://www.sdrl.uc.edu/uff/uff.html.

The Binary 58 Universal File Format (BUFF)

The CoCo-80 and EDM software also support the BUFF format. The basic (ASCII) universal file format for data is universal file format 58. This format is completely documented by SDRC and a copy of that documentation is on the UC-SDRL web site (www.sdrl.uc.edu/UFF2/58.asc). The universal file format always begins with two records that are prior to the information defined by each universal file format and ends with a record that is placed after the information defined by the format. First of all, all records are 80 character ASCII records for the basic universal file format. The first and last record are start/stop records and are always -1 in the first six columns, right

justified (Fortran I6 field with -1 in the field). The second record (Identifier Record) always contains the universal file format number in the first 6 columns, right justified.

This gives a file structure as follows (where b represent a blank character):

bbbb-1
bbbb58
...
...
...
bbbb-1

The Binary 58 universal file format was originally developed by the UC-SDRL in order to eliminate the need to compress the UFF 58 records and to reduce the time required to load the UFF 58 data records. The Binary 58 universal file format yields files that are comparable to compressed files (approximately 3 to 4 times smaller than the equivalent UFF 58 file). The Binary 58 universal file format loads approximately 30 to 40 times faster than the equivalent UFF 58 file, depending upon the computing environment. This new format was submitted to SDRC and subsequently adopted as a supported format.

The Binary 58 universal file format uses the same ASCII records at the start of each data file as the ASCII dataset 58 but, beginning with record 12, the data is stored in binary form rather than the specified ASCII format. The identifier record has the same 58 identifier in the first six columns, right justified, but has additional information in the rest of the 80 character record that identifies the binary format (the size of the binary record, the format of the binary structure, etc.).

```
  -1
  58b   x   y      11     zzzz   0   0      0      0
...
... (11 ASCII header lines)
...
...
... (zzzz BINARY bytes of data, in format specified by x and y, above)
... (interleaved as specified by the ASCII dataset 58)
...
     -1
```

When reading or writing a dataset 58b, care must be taken that the binary data immediately follows the ASCII header lines and the closing ' -1' immediately follows the binary data. The binary data content is written in the same sequence as the ASCII dataset 58 (i.e. field order sequence). The field size is NOT used, however the data type (int/float/double) content is. Note: there are no CR/LF characters embedded in or following the binary data

ASCII UFF

The CoCo-80 and EDM software also support the ASCII UFF format. The ASCII UFF file format is a form using the ASCII type to represent all the data sets. For details, see: http://www.sdrl.uc.edu/uff2/58.asc

MATLAB file

This is the standard file that can be imported into Matlab.

NI-TDM file

This is a structured data format that is defined and widely used by the LabView from National Instruments.

User Defined ASCII file

This is the ASCII files where you have the freedom to define its attributes and header format.

.CSV (Microsoft Excel) File

This is the ASCII file that the Microsoft Excel can directly read.

.WAV File

This is the sound wave files that can be played by most of the media players. Due to limited information a wave file can carry, the wave files exported only contain very basic waveform shape and it does not hold any attribute information of ODS. You are expected to use the .WAV file to listen to its sound effect, instead of for data processing.

APPENDIX

Version

Version	Release Date	Comments
0.2	8/01/07	First Draft
0.90	11/12/07	Revised
0.94	2/15/08	Many pictures added
0.99	7/16/08	Basic manual includes basic, spectral analysis and impact testing.
1.01	2/3/09	Move built-in integration from Advanced to here
1.2	7/16/09	Add descriptions for added 6 buttons. Minor changes
1.3	1/27/2010	Add playback function. Change CI address

Users' Manual Typeface

Headings Arial Black 12 and 11 pt

Body Text: Arial 10 pt

Captions: Arial Narrow 9 pt

Declaration of Conformity

Declaration of Conformity for CI CoCo-80, Handheld Data Acquisition System

Manufacturer: Crystal Instruments Corporation, 4699 Old Ironsides Drive, Suite 100, Santa Clara, CA 95054

Statement of Conformity:

EC Declaration of Conformity

Council Directive 2004/108/EC on Electromagnetic Compatibility

WE, Crystal Instruments

4699 Old Ironsides Drive, Suite 100, Santa Clara, CA 95054, USA.

Product Name: CoCo-80 (Handheld Data Acquisition System)

Model No.: CoCo-80

Assessment of compliance of the product with the requirement relating to Electromagnetic Compatibility Directive .The product has been assessed by the application of the following standards:

EN 61326:1997+A1:1998+A2:2001
EN61000-3-2: 2000
EN61000-3-3: 1995+A1:2001

The tests have been performed in a typical configuration.

This Conformity is indicated by the symbol, i.e. CE "Conformité Européenne".